Supplemental Information for NASA/TM—2011–216470

Generalized Fluid System Simulation Program, Version 5.0—Educational

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APPENDIX D—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 1

Simulation of a Flow System Consisting of a Pump, Valve, and Pipe Line

Contents Page

```
GFSSP VERSION
  503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
ALOK MAJUMDAR
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex1\Ex1.dat
OUTPUT FILE NAME
Ex1.out
TITLE
Simulation of a Flow System Consisting of a Pump, Valve and Pipe Line
USETUP
F
DENCON    GRAVITY    ENERGY      MIXTURE      THRUST     STEADY     TRANSV     SAVER
F         T          T           F            F          T          F          F
HEX       HCOEF       REACTING   INERTIA      CONDX      ADDPROP    PRINTI     ROTATION
F         F          F           F            F          F          T          F
BUOYANCY  HRATE      INVAL       MSORCE       MOVBND     TPA        VARGEO     TVM
F         T          F           F            F          F          F          F
SHEAR     PRNTIN     PRNTADD     OPVALVE      TRANSQ     CONJUG     RADIAT     WINPLOT
F         T          T           F            F          F          F          T
PRESS     INSUC      VARROT      CYCLIC       CHKVALS    WINFILE    DALTON
F         F          F           F            F          T          F
NORMAL    SIMUL      SECONDL     NRSOLVT
F         T          T           F
NNODES    NINT       NBR         NF
 4        2          3           1
RELAXK    RELAXD     RELAXH      CC           NITER
 1        0.5        1           0.0001       500
NFLUID(I), I = 1, NF
 11
NODE    INDEX   DESCRIPTION
 1      2       "Node 1"
 2      1       "Node 2"
 3      1       "Node 3"
 4      2       "Node 4"
NODE    PRES (PSI)    TEMP(DEGF)    MASS SOURC    HEAT SOURC    THRST AREA    CONCENTRATION
 1      14.7          60            0             0             0
 2      14.7          60            0             0             0
 3      14.7          60            0             0             0
 4      14.7          60            0             0             0
INODE   NUMBR   NAMEBR
 2      2       12  23
 3      2       23  34
BRANCH    UPNODE     DNNODE     OPTION     DESCRIPTION
 12       1          2          14         "Pump 12"
 23       2          3          13         "Valve 23"
 34       3          4          1          "Pipe 34"

BRANCH    OPTION -14    PUMP CONST1    PUMP CONST2    PUMP CONST3     AREA
 12                     30888          0              -0.0008067      201.06
BRANCH    OPTION -13    DIA     K1       K2      AREA
 23                     6       1000     0.1     28.274
BRANCH    OPTION -1     LENGTH     DIA     EPSD       ANGLE     AREA
 34                     18000      6       0.005      95.74     28.274
```

```
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        Generalized Fluid System Simulation Program
                    September, 2006
      Developed by NASA/Marshall Space Flight Center
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     A generalized computer program to calculate flow
     rates, pressures, temperatures, and concentrations
     in a flow network.
```

```
TITLE   :Simulation of a Flow System Consisting of a Pump, Valve and Pipe Line
ANALYST :ALOK MAJUMDAR
FILEIN  :C:\Program Files\GFSSP\Examples\Ex1\Ex1.dat
FILEOUT :Ex1.out
  LOGICAL VARIABLES
DENCON   = F
GRAVITY  = T
ENERGY   = T
MIXTURE  = F
THRUST   = F
STEADY   = T
TRANSV   = F
SAVER    = F
HEX      = F
HCOEF    = F
REACTING = F
INERTIA  = F
CONDX    = F
TWOD     = F
PRINTI   = T
ROTATION = F
BUOYANCY = F
HRATE    = T
INVAL    = F
MSORCE   = F
MOVBND   = F
TPA      = F
VARGEO   = F
TVM      = F
SHEAR    = F
PRNTIN   = T
PRNTADD  = T
ADDPROP  = F
PRESS    = F
INSUC    = F
VARROT   = F
NORMAL   = F
SECONDL  = T
CONJUG   = F
NRSOLVT  = F

NNODES   = 4
NINT     = 2
NBR      = 3
NF       = 1
NVAR     = 5
NHREF    = 2

FLUIDS: H2O

BOUNDARY NODES
```

INPUT SPECIFICATIONS FOR INTERNAL NODES

NODE	AREA (IN^2)	MASS (LBM/S)	HEAT (BTU/S)
2	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00

BRANCH	UPNODE	DNNODE	OPTION
12	1	2	14
23	2	3	13
34	3	4	1

BRANCH	OPTION -14:	PUMP CONST1,	PUMP CONST2	PUMP CONST3	AREA
12	0.309E+05	0.000E+00	-0.807E-03	0.201E+03	

BRANCH	OPTION -13:	DIA, K1, K2, AREA		
23	0.600E+01	0.100E+04	0.100E+00	0.283E+02

BRANCH	OPTION -1:	LENGTH, DIA, EPSD, ANGLE, AREA			
34	0.180E+05	0.600E+01	0.500E-02	0.957E+02	0.283E+02

INITIAL GUESS FOR INTERNAL NODES

NODE	P(PSI)	TF(F)	Z(COMP)	RHO (LBM/FT^3)	QUALITY
2	0.1470E+02	0.6000E+02	0.7616E-03	0.6237E+02	0.0000E+00
3	0.1470E+02	0.6000E+02	0.7616E-03	0.6237E+02	0.0000E+00

TRIAL SOLUTION

BRANCH	DELP(PSI)	FLOWRATE(LBM/SEC)
12	0.0000	0.0100
23	0.0000	0.0100
34	0.0000	0.0100

SOLUTION

INTERNAL NODES

NODE	P(PSI)	TF(F)	Z	RHO (LBM/FT^3)	EM(LBM)	QUALITY
2	0.2290E+03	0.6003E+02	0.1186E-01	0.6241E+02	0.0000E+00	0.0000E+00
3	0.2288E+03	0.6003E+02	0.1185E-01	0.6241E+02	0.0000E+00	0.0000E+00

NODE	H BTU/LB	ENTROPY BTU/LB-R	EMU LBM/FT-SEC	COND BTU/FT-S-R	CP BTU/LB-R	GAMA
2	0.2869E+02	0.5542E-01	0.7542E-03	0.9523E-04	0.1000E+01	0.1003E+01
3	0.2869E+02	0.5542E-01	0.7542E-03	0.9523E-04	0.1000E+01	0.1003E+01

BRANCHES

BRANCH	KFACTOR (LBF-S^2/(LBM-FT)^2)	DELP (PSI)	FLOW RATE (LBM/SEC)	VELOCITY (FT/SEC)	REYN. NO.	MACH NO.	ENTROPY GEN. BTU/(R-SEC)	LOST WORK LBF-FT/SEC
12	0.000E+00	-0.214E+03	0.191E+03	0.219E+01	0.241E+06	0.183E-02	0.000E+00	0.000E+00
23	0.764E-03	0.193E+00	0.191E+03	0.156E+02	0.644E+06	0.130E-01	0.210E-03	0.848E+02
34	0.591E+00	0.214E+03	0.191E+03	0.156E+02	0.644E+06	0.130E-01	0.162E+00	0.657E+05

***** TOTAL ENTROPY GENERATION = 0.163E+00 BTU/(R-SEC) ******

**** TOTAL WORK LOST = 0.120E+03 HP *****

SOLUTION SATISFIED CONVERGENCE CRITERION OF 0.100E-03 IN 5 ITERATIONS
TAU = 100000000.000000 ISTEP = 1

TIME OF ANALYSIS WAS 1.001440000000000E-002 SECS

APPENDIX E—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 2

Simulation of a Water Distribution Network

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
Alok Majumdar
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex2\Ex2.dat
OUTPUT FILE NAME
Ex2.out
TITLE
Simulation of a water distribution network
USETUP
F
DENCON      GRAVITY     ENERGY      MIXTURE     THRUST      STEADY      TRANSV      SAVER
T           F           F           F           F           T           F           F
HEX         HCOEF       REACTING    INERTIA     CONDX       ADDPROP     PRINTI      ROTATION
F           F           F           F           F           F           T           F
BUOYANCY    HRATE       INVAL       MSORCE      MOVBND      TPA         VARGEO      TVM
F           F           F           F           F           F           F           F
SHEAR       PRNTIN      PRNTADD     OPVALVE     TRANSQ      CONJUG      RADIAT      WINPLOT
F           T           T           F           F           F           F           T
PRESS        INSUC      VARROT      CYCLIC      CHKVALS     WINFILE     DALTON
F           F           F           F           F           T           F
NORMAL      SIMUL       SECONDL     NRSOLVT
F           T           T           F
NNODES      NINT        NBR         NF
 9          5           10          0
RELAXK      RELAXD      RELAXH      CC          NITER
 1          0.5         1           0.0001      500
RHOREF      EMUREF
 62.4       0.00066
NODE      INDEX       DESCRIPTION
 1        2           "Node 1"
 2        1           "Node 2"
 3        2           "Node 3"
 4        2           "Node 4"
 5        1           "Node 5"
 6        1           "Node 6"
 7        1           "Node 7"
 8        1           "Node 8"
 9        2           "Node 9"
NODE     PRES (PSI)    MASS SOURC     HEAT SOURC      THRST AREA
 1       50            0              0               0
 2       49.6          0              0               0
 3       48            0              0               0
 4       45            0              0               0
 5       48.4          0              0               0
 6       47.4          0              0               0
 7       49.2          0              0               0
 8       46.4          0              0               0
 9       46            0              0               0
INODE      NUMBR        NAMEBR
 2         3            12    25    27
 5         4            25    53    57   56
 6         3            56    68    64
 7         3            27    57    78
 8         3            78    68    89
```

BRANCH	UPNODE	DNNODE	OPTION	DESCRIPTION
12	1	2	1	"Pipe 12"
25	2	5	1	"Pipe 25"
27	2	7	1	"Pipe 27"
53	5	3	1	"Pipe 53"
57	5	7	1	"Pipe 57"
56	5	6	1	"Pipe 56"
78	7	8	1	"Pipe 78"
68	6	8	1	"Pipe 68"
64	6	4	1	"Pipe 64"
89	8	9	1	"Pipe 89"

BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
12		120	6	0.0018	0	28.274
BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
25		2400	6	0.0018	0	28.274
BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
27		2400	5	0.0018	0	19.635
BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
53		120	5	0.0018	0	19.635
BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
57		1440	4	0.0018	0	12.566
BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
56		2400	4	0.0018	0	12.566
BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
78		2400	4	0.0018	0	12.566
BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
68		1440	4	0.0018	0	12.566
BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
64		120	4	0.0018	0	12.566
BRANCH	OPTION -1	LENGTH	DIA	EPSD	ANGLE	AREA
89		120	5	0.0018	0	19.635

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     A generalized computer program to calculate flow
     rates, pressures, temperatures and concentrations
     in a flow network.
```

```
TITLE   :Simulation of a water distribution network
ANALYST :Alok Majumdar
FILEIN  :C:\Program Files\GFSSP\Examples\Ex2\Ex2.dat
FILEOUT :Ex2.out
LOGICAL VARIABLES

 3      0.4800E+02     0.0000E+00
 4      0.4500E+02     0.0000E+00
 9      0.4600E+02     0.0000E+00

INPUT   SPECIFICATIONS FOR INTERNAL NODES
 NODE     AREA           MASS          HEAT
          (IN^2)         (LBM/S)       BTU/LBM)
  2       0.0000E+00     0.0000E+00    0.0000E+00
  5       0.0000E+00     0.0000E+00    0.0000E+00
  6       0.0000E+00     0.0000E+00    0.0000E+00
  7       0.0000E+00     0.0000E+00    0.0000E+00
  8       0.0000E+00     0.0000E+00    0.0000E+00

BRANCH    UPNODE     DNNODE    OPTION
 12       1          2         1
 25       2          5         1
 27       2          7         1
 53       5          3         1
 57       5          7         1
 56       5          6         1
 78       7          8         1
 68       6          8         1
 64       6          4         1
 89       8          9         1

BRANCH    OPTION-1:     LENGTH         DIA           EPSD          ANGLE         AREA
 12                     0.120E+03      0.600E+01     0.180E-02     0.000E+00     0.283E+02
 25                     0.240E+04      0.600E+01     0.180E-02     0.000E+00     0.283E+02
 27                     0.240E+04      0.500E+01     0.180E-02     0.000E+00     0.196E+02
 53                     0.120E+03      0.500E+01     0.180E-02     0.000E+00     0.196E+02
 57                     0.144E+04      0.400E+01     0.180E-02     0.000E+00     0.126E+02
 56                     0.240E+04      0.400E+01     0.180E-02     0.000E+00     0.126E+02
 78                     0.240E+04      0.400E+01     0.180E-02     0.000E+00     0.126E+02
 68                     0.144E+04      0.400E+01     0.180E-02     0.000E+00     0.126E+02
 64                     0.120E+03      0.400E+01     0.180E-02     0.000E+00     0.126E+02
 89                     0.120E+03      0.500E+01     0.180E-02     0.000E+00     0.196E+02

INITIAL GUESS FOR INTERNAL NODES

NODE    P(PSI)
 2      0.4960E+02
 5      0.4840E+02
 6      0.4740E+02
 7      0.4920E+02
 8      0.4640E+02
```

TRIAL SOLUTION

BRANCH	DELP(PSI)	FLOWRATE(LBM/SEC)
12	0.0000	0.0100
25	0.0000	0.0100
27	0.0000	0.0100
53	0.0000	0.0100
57	0.0000	0.0100
56	0.0000	0.0100
78	0.0000	0.0100
68	0.0000	0.0100
64	0.0000	0.0100
89	0.0000	0.0100

SOLUTION

INTERNAL NODES

NODE	P(PSI)	EM(LBM)
2	0.4979E+02	0.0000E+00
5	0.4810E+02	0.0000E+00
6	0.4535E+02	0.0000E+00
7	0.4833E+02	0.0000E+00
8	0.4600E+02	0.0000E+00

BRANCHES

BRANCH	KFACTOR (LBF-S^2/ (LBM-FT)^2)	DELP (PSI)	FLOW RATE (LBM/SEC)	VELOCITY (FT/SEC)	REYN. NO.	MACH NO.	ENTROPY GEN. BTU/(R-SEC)	LOST WORK LBF-FT/SEC
12	0.301E-02	0.210E+00	0.100E+03	0.817E+01	0.386E+06	0.000E+00	0.135E-03	0.484E+02
25	0.609E-01	0.169E+01	0.631E+02	0.515E+01	0.244E+06	0.000E+00	0.687E-03	0.246E+03
27	0.154E+00	0.146E+01	0.370E+02	0.435E+01	0.171E+06	0.000E+00	0.349E-03	0.125E+03
53	0.762E-02	0.104E+00	0.444E+02	0.522E+01	0.206E+06	0.000E+00	0.300E-04	0.107E+02
57	0.301E+00	-0.224E+00	-0.104E+02	-0.190E+01	0.599E+05	0.000E+00	0.150E-04	0.536E+01
56	0.469E+00	0.275E+01	0.291E+02	0.534E+01	0.168E+06	0.000E+00	0.516E-03	0.184E+03
78	0.471E+00	0.232E+01	0.267E+02	0.490E+01	0.154E+06	0.000E+00	0.400E-03	0.143E+03
68	0.289E+00	-0.650E+00	-0.180E+02	-0.331E+01	0.104E+06	0.000E+00	0.755E-04	0.270E+02
64	0.230E-01	0.355E+00	0.471E+02	0.864E+01	0.272E+06	0.000E+00	0.108E-03	0.385E+02
89	0.858E-02	0.447E-02	0.866E+01	0.102E+01	0.401E+05	0.000E+00	0.249E-06	0.892E-01

***** TOTAL ENTROPY GENERATION = 0.232E-02 BTU/(R-SEC) ******

**** TOTAL WORK LOST = 0.151E+01 HP *****

SOLUTION SATISFIED CONVERGENCE CRITERION OF 0.100E-03 IN 11 ITERATIONS
TAU = 100000000.000000 ISTEP = 1

TIME OF ANALYSIS WAS 2.002880000000000E-002 SECS

APPENDIX F—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 3

Simulation of Compressible Flow in a Converging-Diverging Nozzle

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
jwb
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex3\Ex3.dat
OUTPUT FILE NAME
Ex3.out
TITLE
Simulation of Compressible Flow in a Converging-Diverging Nozzle
USETUP
F
DENCON    GRAVITY   ENERGY      MIXTURE     THRUST     STEADY      TRANSV     SAVER
F         F         T           F           F          T           F          F
HEX       HCOEF     REACTING    INERTIA     CONDX      ADDPROP     PRINTI     ROTATION
F         F         F           T           F          F           F          F
BUOYANCY  HRATE     INVAL       MSORCE      MOVBND     TPA         VARGEO     TVM
F         F         F           F           F          F           F          F
SHEAR     PRNTIN    PRNTADD     OPVALVE     TRANSQ     CONJUG      RADIAT     WINPLOT
F         F         F           F           F          F           F          T
PRESS     INSUC     VARROT      CYCLIC      CHKVALS    WINFILE     DALTON
F         F         F           F           F          T           F
NORMAL    SIMUL     SECONDL     NRSOLVT
F         T         T           F
NNODES    NINT      NBR         NF
 17       15        16          1
RELAXK    RELAXD    RELAXH      CC          NITER
 1        0.5       1           0.0001      500
NFLUID(I), I = 1, NF
 11
NODE    INDEX   DESCRIPTION
 1      2       "Node 1"
 2      1       "Node 2"
 3      1       "Node 3"
 4      1       "Node 4"
 5      1       "Node 5"
 6      1       "Node 6"
 7      1       "Node 7"
 8      1       "Node 8"
 9      1       "Node 9"
 10     1       "Node 10"
 11     1       "Node 11"
 12     1       "Node 12"
 13     1       "Node 13"
 14     1       "Node 14"
 15     1       "Node 15"
 16     1       "Node 16"
 17     2       "Node 17"
NODE    PRES (PSI)    TEMP(DEGF)    MASS SOURC    HEAT SOURC   THRST AREA    CONCENTRATION
 1      150           1000          0             0            0
 2      14.7          60            0             0            0
 3      14.7          60            0             0            0
 4      14.7          60            0             0            0
 5      14.7          60            0             0            0
 6      14.7          60            0             0            0
 7      14.7          60            0             0            0
 8      14.7          60            0             0            0
 9      14.7          60            0             0            0
 10     14.7          60            0             0            0
 11     14.7          60            0             0            0
 12     14.7          60            0             0            0
 13     14.7          60            0             0            0
 14     14.7          60            0             0            0
 15     14.7          60            0             0            0
 16     14.7          60            0             0            0
 17     60            1000          0             0            0
```

```
INODE    NUMBR     NAMEBR
 2       2         12      23
 3       2         23      34
 4       2         34      45
 5       2         45      56
 6       2         56      67
 7       2         67      78
 8       2         78      89
 9       2         89      910
 10      2         910     1011
 11      2         1011    1112
 12      2         1112    1213
 13      2         1213    1314
 14      2         1314    1415
 15      2         1415    1516
 16      2         1516    1617
BRANCH   UPNODE      DNNODE     OPTION     DESCRIPTION
 12      1           2          2          "Restrict 12"
 23      2           3          2          "Restrict 23"
 34      3           4          2          "Restrict 34"
 45      4           5          2          "Restrict 45"
 56      5           6          2          "Restrict 56"
 67      6           7          2          "Restrict 67"
 78      7           8          2          "Restrict 78"
 89      8           9          2          "Restrict 89"
 910     9           10         2          "Restrict 910"
 1011    10          11         2          "Restrict 1011"
 1112    11          12         2          "Restrict 1112"
 1213    12          13         2          "Restrict 1213"
 1314    13          14         2          "Restrict 1314"
 1415    14          15         2          "Restrict 1415"
 1516    15          16         2          "Restrict 1516″
 1617    16          17         2          "Restrict 1617"
BRANCH   OPTION -2   FLOW COEFF      AREA
 12                  0               0.3587
BRANCH   OPTION -2   FLOW COEFF      AREA
 23                  0               0.2717
BRANCH   OPTION -2   FLOW COEFF      AREA
 34                  0               0.2243
BRANCH   OPTION -2   FLOW COEFF      AREA
 45                  0               0.2083
BRANCH   OPTION -2   FLOW COEFF      AREA
 56                  0               0.1901
BRANCH   OPTION -2   FLOW COEFF      AREA
 67                  0               0.1949
BRANCH   OPTION -2   FLOW COEFF      AREA
 78                  0               0.2255
BRANCH   OPTION -2   FLOW COEFF      AREA
 89                  0               0.2875
BRANCH   OPTION -2   FLOW COEFF      AREA
 910                 0               0.3948
BRANCH   OPTION -2   FLOW COEFF      AREA
 1011                0               0.564
BRANCH   OPTION -2   FLOW COEFF      AREA
 1112                0               0.7633
BRANCH   OPTION -2   FLOW COEFF      AREA
 1213                0               0.9927
BRANCH   OPTION -2   FLOW COEFF      AREA
 1314                0               1.252
BRANCH   OPTION -2   FLOW COEFF      AREA
 1415                0               1.4668
BRANCH   OPTION -2   FLOW COEFF      AREA
 1516                0               1.5703
BRANCH   OPTION -2   FLOW COEFF      AREA
 1617                0               1.6286
```

```
BRANCH      NOUBR      NMUBR
 12         0
 23         1          12
 34         1          23
 45         1          34
 56         1          45
 67         1          56
 78         1          67
 89         1          78
 910        1          89
 1011       1          910
 1112       1          1011
 1213       1          1112
 1314       1          1213
 1415       1          1314
 1516       1          1415
 1617       1          1516
BRANCH      NODBR      NMDBR
 12         1          23
 23         1          34
 34         1          45
 45         1          56
 56         1          67
 67         1          78
 78         1          89
 89         1          910
 910        1          1011
 1011       1          1112
 1112       1          1213
 1213       1          1314
 1314       1          1415
 1415       1          1516
 1516       1          1617
 1617       0
BRANCH
 12
 UPSTRM BR.     ANGLE
 DNSTRM BR.     ANGLE
   23           0.00000
BRANCH
 23
 UPSTRM BR.     ANGLE
   12           0.00000
 DNSTRM BR.     ANGLE
   34           0.00000
BRANCH
 34
 UPSTRM BR.     ANGLE
   23           0.00000
 DNSTRM BR.     ANGLE
   45           0.00000
BRANCH
 45
 UPSTRM BR.     ANGLE
   34           0.00000
 DNSTRM BR.     ANGLE
   56           0.00000
BRANCH
 56
 UPSTRM BR.     ANGLE
   45           0.00000
 DNSTRM BR.     ANGLE
   67           0.00000
BRANCH
 67
 UPSTRM BR.     ANGLE
   56           0.00000
 DNSTRM BR.     ANGLE
   78           0.00000
BRANCH
 78
```

```
 UPSTRM BR.     ANGLE
   67           0.00000
 DNSTRM BR.     ANGLE
   89           0.00000
BRANCH
 89
 UPSTRM BR.     ANGLE
   78           0.00000
 DNSTRM BR.     ANGLE
   910          0.00000
BRANCH
 910
 UPSTRM BR.     ANGLE
   89           0.00000
 DNSTRM BR.     ANGLE
   1011         0.00000
BRANCH
 1011
 UPSTRM BR.     ANGLE
   910          0.00000
 DNSTRM BR.     ANGLE
   1112         0.00000
BRANCH
 1112
 UPSTRM BR.     ANGLE
   1011         0.00000
 DNSTRM BR.     ANGLE
   1213         0.00000
BRANCH
 1213
 UPSTRM BR.     ANGLE
   1112         0.00000
 DNSTRM BR.     ANGLE
   1314         0.00000
BRANCH
 1314
 UPSTRM BR.     ANGLE
   1213         0.00000
 DNSTRM BR.     ANGLE
   1415         0.00000
BRANCH
 1415
 UPSTRM BR.     ANGLE
   1314         0.00000
 DNSTRM BR.     ANGLE
   1516         0.00000
BRANCH
 1516
 UPSTRM BR.     ANGLE
   1415         0.00000
 DNSTRM BR.     ANGLE
   1617         0.00000
BRANCH
 1617
 UPSTRM BR.     ANGLE
   1516         0.00000
 DNSTRM BR.     ANGLE
```

```
NUMBER OF BRANCHES WITH INERTIA
 16
 12
 23
 34
 45
 56
 67
 78
 89
 910
 1011
 1112
 1213
 1314
 1415
 1516
 1617
```

```
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          Generalized Fluid System Simulation Program
                       September, 2006
        Developed by NASA/Marshall Space Flight Center
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     A generalized computer program to calculate flow
     rates, pressures, temperatures and concentrations
     in a flow network.
```

```
 TITLE      :Simulation of Compressible Flow in a Converging-Diverging Nozzle
 ANALYST    :jwb
 FILEIN     :C:\Program Files\GFSSP\Examples\Ex3\Ex3.dat
 FILEOUT    :Ex3.out
 LOGICAL VARIABLES
  DENCON    = F
  GRAVITY   = F
  ENERGY    = T
  MIXTURE   = F
  THRUST    = F
  STEADY    = T
  TRANSV    = F
  SAVER     = F
  HEX       = F
  HCOEF     = F
  REACTING  = F
  INERTIA   = T
  CONDX     = F
  TWOD      = F
  PRINTI    = F
  ROTATION  = F
  BUOYANCY  = F
  HRATE     = F
  INVAL     = F
  MSORCE    = F
  MOVBND    = F
  TPA       = F
  VARGEO    = F
  TVM       = F
  SHEAR     = F
  PRNTIN    = F
  PRNTADD   = F
  ADDPROP   = F
  PRESS     = F
  INSUC     = F
  VARROT    = F
  NORMAL    = F
  SECONDL   = T
  CONJUG    = F
  NRSOLVT   = F

  NNODES    = 17
  NINT      = 15
  NBR       = 16
  NF        = 1
  NVAR      = 31
  NHREF     = 2

 FLUIDS: H2O

 BOUNDARY NODES
  NODE      P             T             RHO           AREA
            (PSI)         (F)           (LBM/FT^3)    (IN^2)
  1         0.1500E+03    0.1000E+04    0.1736E+00    0.0000E+00
  17        0.6000E+02    0.1000E+04    0.6919E-01    0.0000E+00
```

SOLUTION

INTERNAL NODES

NODE	P(PSI)	TF(F)	Z	RHO (LBM/FT^3)	EM(LBM)	QUALITY
2	0.1500E+03	0.1000E+04	0.9939E+00	0.1736E+00	0.0000E+00	0.1000E+01
3	0.1373E+03	0.9725E+03	0.9939E+00	0.1620E+00	0.0000E+00	0.1000E+01
4	0.1197E+03	0.9305E+03	0.9941E+00	0.1455E+00	0.0000E+00	0.1000E+01
5	0.1045E+03	0.8897E+03	0.9942E+00	0.1308E+00	0.0000E+00	0.1000E+01
6	0.8213E+02	0.8199E+03	0.9944E+00	0.1084E+00	0.0000E+00	0.1000E+01
7	0.5974E+02	0.7321E+03	0.9946E+00	0.8463E-01	0.0000E+00	0.1000E+01
8	0.4267E+02	0.6445E+03	0.9948E+00	0.6523E-01	0.0000E+00	0.1000E+01
9	0.3498E+02	0.5953E+03	0.9949E+00	0.5597E-01	0.0000E+00	0.1000E+01
10	0.4116E+02	0.6354E+03	0.9949E+00	0.6344E-01	0.0000E+00	0.1000E+01
11	0.5165E+02	0.6935E+03	0.9947E+00	0.7561E-01	0.0000E+00	0.1000E+01
12	0.5650E+02	0.7172E+03	0.9946E+00	0.8106E-01	0.0000E+00	0.1000E+01
13	0.5839E+02	0.7260E+03	0.9946E+00	0.8315E-01	0.0000E+00	0.1000E+01
14	0.5930E+02	0.7301E+03	0.9946E+00	0.8415E-01	0.0000E+00	0.1000E+01
15	0.5974E+02	0.7321E+03	0.9946E+00	0.8463E-01	0.0000E+00	0.1000E+01
16	0.5991E+02	0.7328E+03	0.9946E+00	0.8483E-01	0.0000E+00	0.1000E+01

BRANCHES

BRANCH	KFACTOR (LBF-S^2/ (LBM-FT)^2)	DELP (PSI)	FLOW RATE (LBM/SEC)	VELOCITY (FT/SEC)	REYN. NO.	MACH NO.	ENTROPY GEN. BTU/(R-SEC)	LOST WORK LBF-FT/SEC
12	0.000E+00	0.000E+00	0.336E+00	0.778E+03	0.376E+06	0.342E+00	0.000E+00	0.000E+00
23	0.000E+00	0.127E+02	0.336E+00	0.103E+04	0.432E+06	0.452E+00	0.000E+00	0.000E+00
34	0.000E+00	0.176E+02	0.336E+00	0.133E+04	0.485E+06	0.592E+00	0.000E+00	0.000E+00
45	0.000E+00	0.153E+02	0.336E+00	0.160E+04	0.520E+06	0.720E+00	0.000E+00	0.000E+00
56	0.000E+00	0.223E+02	0.336E+00	0.195E+04	0.563E+06	0.890E+00	0.000E+00	0.000E+00
67	0.000E+00	0.224E+02	0.336E+00	0.229E+04	0.591E+06	0.107E+01	0.000E+00	0.000E+00
78	0.000E+00	0.171E+02	0.336E+00	0.254E+04	0.595E+06	0.123E+01	0.000E+00	0.000E+00
89	0.000E+00	0.769E+01	0.336E+00	0.258E+04	0.576E+06	0.130E+01	0.000E+00	0.000E+00
910	0.000E+00	-0.618E+01	0.336E+00	0.219E+04	0.518E+06	0.112E+01	0.000E+00	0.000E+00
1011	0.000E+00	-0.105E+02	0.336E+00	0.135E+04	0.415E+06	0.682E+00	0.000E+00	0.000E+00
1112	0.000E+00	-0.485E+01	0.336E+00	0.840E+03	0.336E+06	0.413E+00	0.000E+00	0.000E+00
1213	0.000E+00	-0.189E+01	0.336E+00	0.602E+03	0.288E+06	0.293E+00	0.000E+00	0.000E+00
1314	0.000E+00	-0.903E+00	0.336E+00	0.465E+03	0.254E+06	0.226E+00	0.000E+00	0.000E+00
1415	0.000E+00	-0.443E+00	0.336E+00	0.393E+03	0.234E+06	0.190E+00	0.000E+00	0.000E+00
1516	0.000E+00	-0.174E+00	0.336E+00	0.365E+03	0.226E+06	0.177E+00	0.000E+00	0.000E+00
1617	0.000E+00	-0.857E-01	0.336E+00	0.351E+03	0.221E+06	0.170E+00	0.000E+00	0.000E+00

***** TOTAL ENTROPY GENERATION = 0.000E+00 BTU/(R-SEC) ******

**** TOTAL WORK LOST = 0.000E+00 HP *****

TIME OF ANALYSIS WAS 0.300432000000000 SECS

APPENDIX G—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 4

Simulation of the Mixing of Combustion Gases and a Cold Gas Stream

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
ALOK MAJUMDAR
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex4\Ex4.dat
OUTPUT FILE NAME
Ex4.out
TITLE
Simulation of the Mixing of Combustion Gases and a Cold Gas Stream
USETUP
F
DENCON      GRAVITY     ENERGY      MIXTURE     THRUST     STEADY      TRANSV     SAVER
F           F           T           T           F          T           F          F
HEX         HCOEF       REACTING    INERTIA     CONDX      ADDPROP     PRINTI     ROTATION
F           F           F           F           F          F           T          F
BUOYANCY    HRATE       INVAL       MSORCE      MOVBND     TPA         VARGEO     TVM
 F          T           F           F           F          F           F          F
SHEAR       PRNTIN      PRNTADD     OPVALVE     TRANSQ     CONJUG      RADIAT     WINPLOT
F           T           T           F           F          F           F          T
PRESS       INSUC        VARROT     CYCLIC      CHKVALS    WINFILE     DALTON
F           F           F           F           F          T           F
NORMAL      SIMUL       SECONDL     NRSOLVT
F           F           T           F
NNODES      NINT        NBR         NF
4           1           3           2
RELAXK      RELAXD      RELAXH      CC          NITER
1           0.5         0.75        0.0001      500
NFLUID(I), I = 1, NF
 6 11
NODE    INDEX     DESCRIPTION
 1      2         "Node 1"
 2      2         "Node 2"
 3      1         "Node 3"
 4      2         "Node 4"
NODE      PRES(PSI)     TEMP(DEGF)     MASS SOURC     HEAT SOURC     THRST AREA     CONCENTRATION
 1        500           1500           0              0              0              0.1      0.9
 2        500           80             0              0              0              1 0
 3        338.2         1500           0              0              0              0.1      0.9
 4        14.7          80             0              0              0              0.5      0.5
INODE   NUMBR   NAMEBR
 3      3       13      23      34
BRANCH    UPNODE    DNNODE     OPTION      DESCRIPTION
 13       1         3          2           "Restrict 13"
 23       2         3          2           "Restrict 23"
 34       3         4          22          "Orifice 34"
BRANCH    OPTION -2     FLOW COEFF      AREA
 13                     0.6             1
BRANCH    OPTION -2     FLOW COEFF      AREA
 23                     0.6             1
BRANCH    OPTION -22    AREA            FLOW COEF
 34                     1               0.6
```

```
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        Generalized Fluid System Simulation Program
                    September, 2006
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     A generalized computer program to calculate flow
     rates, pressures, temperatures and concentrations
     in a flow network.
```

```
TITLE     :Simulation of the Mixing of Combustion Gases and a Cold Gas Stream
ANALYST   :ALOK MAJUMDAR
FILEIN    :C:\Program Files\GFSSP\Examples\Ex4\Ex4.dat
FILEOUT   :Ex4.out
LOGICAL VARIABLES
 DENCON   = F
 GRAVITY  = F
 ENERGY   = T
 MIXTURE = T
 THRUST   = F
 STEADY   = T
 TRANSV   = F
 SAVER    = F
 HEX      = F
 HCOEF    = F
 REACTING= F
 INERTIA  = F
 CONDX    = F
 TWOD     = F
 PRINTI   = T
 ROTATION= F
 BUOYANCY= F
 HRATE    = T
 INVAL    = F
 MSORCE   = F
 MOVBND   = F
 TPA      = F
 VARGEO   = F
 TVM      = F
 SHEAR    = F
 PRNTIN   = T
 PRNTADD  = T
 ADDPROP  = F
 PRESS    = F
 INSUC    = F
 VARROT   = F
 NORMAL   = F
 SECONDL  = T
 CONJUG   = F
 NRSOLVT  = F

 NNODES   = 4
 NINT     = 1
 NBR      = 3
 NF       = 2
 NVAR     = 4
 NHREF    = 2
```

```
FLUIDS: O2     H2O

BOUNDARY NODES
  NODE      P             T             RHO           AREA          CONCENTRATIONS
            (PSI)         (F)           (LBM/FT^3)    (IN^2)        O2             H2O
   1        0.5000E+03    0.1500E+04    0.3931E+00    0.0000E+00    0.1000E+00     0.9000E+00
   2        0.5000E+03    0.8000E+02    0.2819E+01    0.0000E+00    0.1000E+01     0.0000E+00
   4        0.1470E+02    0.8000E+02    0.4725E+02    0.0000E+00    0.5000E+00     0.5000E+00
INPUT SPECIFICATIONS FOR INTERNAL NODES
NODE    AREA           MASS           HEAT
        (IN^2)         (LBM/S)        (BTU/S)
 3      0.0000E+00     0.0000E+00     0.0000E+00
BRANCH      UPNODE     DNNODE     OPTION
 13         1          3          2
 23         2          3          2
 34         3          4          22
BRANCH    OPTION-2     FLOW COEF     AREA
 13                    0.600E+00     0.100E+01
BRANCH    OPTION-2     FLOW COEF     AREA
 23                    0.600E+00     0.100E+01
BRANCH    OPTION-22    FLOW COEF     AREA
 34                    0.600E+00     0.100E+01
INITIAL GUESS FOR INTERNAL NODES
NODE    P(PSI)        TF(F)         Z(COMP)       RHO           CONCENTRATIONS
                                    (LBM/FT^3)                  O2             H2O
 3      0.3382E+03    0.1500E+04    0.9966E+00    0.2984E+00    0.1000E+00     0.9000E+00
TRIAL SOLUTION
BRANCH      DELP(PSI)     FLOWRATE(LBM/SEC)
 13         0.0000        0.0100
 23         0.0000        0.0100
 34         0.0000        0.0100

SOLUTION
 INTERNAL NODES
NODE      P(PSI)        TF(F)          Z             RHO           EM(LBM)          CONCENTRATIONS
                                                     (LBM/FT^3)                     O2           H2O
 3        0.4788E+03    0.6886E+03     0.9862E+00    0.1060E+01    0.0000E+00       0.7553E+00   0.2447

NODE      H             ENTROPY        EMU           COND          CP               GAMA
          BTU/LB        BTU/LB-R       LBM/FT-SEC    BTU/FT-S-R    BTU/LB-R
 3        0.7213E+03    0.1527E+01     0.2079E-04    0.8153E-05    0.3757E+00       0.1297E+01

BRANCHES
BRANCH    KFACTOR       DELP        FLOW RATE    VELOCITY     REYN. NO.    MACH NO.   ENTROPY GEN.   LOST WORK
          (LBF-S^2/     (PSI)       (LBM/SEC)    (FT/SEC)                             BTU/(R-SEC)    LBF-FT/SEC
          (LBM-FT)^2)
 13       0.228E+04     0.212E+02   0.116E+01    0.424E+03    0.560E+06   0.166E+00   0.590E-02      0.900E+04
 23       0.317E+03     0.212E+02   0.310E+01    0.158E+03    0.294E+07   0.143E+00   0.800E-02      0.336E+04
 34       0.317E+03     0.464E+03   0.426E+01    0.579E+03    0.277E+07   0.336E+00   0.259E-01      0.232E+05

         ***** TOTAL ENTROPY GENERATION =     0.398E-01 BTU/(R-SEC) ******

         **** TOTAL WORK LOST =       0.646E+02 HP *****

WARNING! CHKGASP: T out of fluid property range at node     1
WARNING! CHKGASP: T out of fluid property range at node     3

SOLUTION SATISFIED CONVERGENCE CRITERION OF  0.100E-03 IN   27 ITERATIONS
TAU =     100000000.000000           ISTEP =     1
```

```
TIME OF ANALYSIS WAS  2.002880000000000E-002 SECS
```

APPENDIX H—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 5

Simulation of a Flow System Involving a Heat Exchanger

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
Todd Steadman
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex5\Ex5.dat
OUTPUT FILE NAME
Ex5.out
TITLE
Simulation of a Flow System Involving a Heat Exchanger
USETUP
F
DENCON      GRAVITY     ENERGY      MIXTURE     THRUST      STEADY      TRANSV      SAVER
F           F           T           F           F           T           F           F
HEX         HCOEF       REACTING    INERTIA     CONDX       ADDPROP     PRINTI      ROTATION
T           T           F           F           F           F           F           F
BUOYANCY    HRATE       INVAL       MSORCE      MOVBND      TPA         VARGEO      TVM
F           T           F           F           F           F           F           F
SHEAR       PRNTIN      PRNTADD     OPVALVE     TRANSQ      CONJUG      RADIAT      WINPLOT
F           T           F           F           F           F           F           T
PRESS       INSUC       VARROT      CYCLIC      CHKVALS     WINFILE     DALTON
F           F           F           F           F           T           F
NORMAL      SIMUL       SECONDL     NRSOLVT
F           T           T           F
NNODES      NINT        NBR         NF
 8          4           6           1
RELAXK      RELAXD      RELAXH      CC          NITER
 1          0.5         1           0.0001      500
NFLUID(I), I = 1, NF
 11
NODE      INDEX         DESCRIPTION
 1        2             "Node 1"
 2        1             "Node 2"
 3        1             "Node 3"
 4        2             "Node 4"
 5        2             "Node 5"
 6        1             "Node 6"
 7        1             "Node 7"
 8        2             "Node 8"
NODE       PRES (PSI)    TEMP(DEGF)    MASS SOURC     HEAT SOURC     THRST AREA     CONCENTRATION
 1         50            100            0              0              0
 2         14.7          60             0              0              0
 3         14.7          60             0              0              0
 4         25            60             0              0              0
 5         50            60             0              0              0
 6         14.7          60             0              0              0
 7         14.7          60             0              0              0
 8         25            60             0              0              0
INODE      NUMBR      NAMEBR
 2         2          12     23
 3         2          23     34
 6         2          56     67
 7         2          67     78
BRANCH     UPNODE     DNNODE       OPTION      DESCRIPTION
 12        1          2            1           “Pipe 12”
 23        2          3            1           “Pipe 23”
 34        3          4            1           “Pipe 34”
 56        5          6            1           “Pipe 56”
 67        6          7            1           “Pipe 67”
 78        7          8            1           “Pipe 78”
BRANCH   OPTION -1   LENGTH       DIA         EPSD       ANGLE       AREA
 12                  10           0.25        0          0           0.049087
BRANCH   OPTION -1   LENGTH       DIA         EPSD       ANGLE       AREA
 23                  10           0.25        0          0           0.049087
BRANCH   OPTION -1   LENGTH       DIA         EPSD       ANGLE       AREA
 34                  10           0.25        0          0           0.049087
BRANCH   OPTION -1   LENGTH       DIA         EPSD       ANGLE       AREA
 56                  10           0.5         0          0            0.19635
BRANCH   OPTION -1   LENGTH       DIA         EPSD       ANGLE        AREA
```

```
 67                 10          0.5         0          0           0.19635
BRANCH   OPTION -1   LENGTH      DIA         EPSD       ANGLE       AREA
 78                 10          0.5         0          0           0.19635
NUMBER OF HEAT EXCHANGERS
 1
IBRHOT      IBRCLD      ITYPHX        ARHOT       ARCOLD       UA           HEXEFF
 23         67          1             0           0            1.1038       1.5
```

```
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          Generalized Fluid System Simulation Program
                       September, 2006
        Developed by NASA/Marshall Space Flight Center
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     A generalized computer program to calculate flow
     rates, pressures, temperatures and concentrations
     in a flow network.
```

```
 TITLE     :Simulation of a Flow System Involving a Heat Exchanger
 ANALYST   :Todd Steadman
 FILEIN    :C:\Program Files\GFSSP\Examples\Ex5\Ex5.dat
 FILEOUT   :Ex5.out
 LOGICAL VARIABLES
  DENCON   = F
  GRAVITY  = F
  ENERGY   = T
  MIXTURE  = F
  THRUST   = F
  STEADY   = T
  TRANSV   = F
  SAVER    = F
  HEX      = T
  HCOEF    = T
  REACTING = F
  INERTIA  = F
  CONDX    = F
  TWOD     = F
  PRINTI   = F
  ROTATION = F
  BUOYANCY = F
  HRATE    = T
  INVAL    = F
  MSORCE   = F
  MOVBND   = F
  TPA      = F
  VARGEO   = F
  TVM      = F
  SHEAR    = F
  PRNTIN   = T
  PRNTADD  = F
  ADDPROP  = F
  PRESS    = F
  INSUC    = F
  VARROT   = F
  NORMAL   = F
  SECONDL  = T
  CONJUG   = F
  NRSOLVT  = F

  NNODES   = 8
  NINT     = 4
  NBR      = 6
  NF       = 1
  NVAR     = 10
  NHREF    = 2
```

FLUIDS: H2O

BOUNDARY NODES

NODE (PSI)	P (F)	T (LBM/FT^3)	RHO (IN^2)	AREA
1	0.5000E+02	0.1000E+03	0.6201E+02	0.0000E+00
4	0.2500E+02	0.6000E+02	0.6237E+02	0.0000E+00
5	0.5000E+02	0.6000E+02	0.6238E+02	0.0000E+00
8	0.2500E+02	0.6000E+02	0.6237E+02	0.0000E+00

INPUT SPECIFICATIONS FOR INTERNAL NODES

NODE	AREA (IN^2)	MASS (LBM/S)	HEAT (BTU/S)
2	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00
7	0.0000E+00	0.0000E+00	0.0000E+00

BRANCH	UPNODE	DNNODE	OPTION
	12	1	2 1
	23	2	3 1
	34	3	4 1
	56	5	6 1
	67	6	7 1
	78	7	8 1

BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
12	0.100E+02	0.250E+00	0.000E+00	0.000E+00	0.491E-01
BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
23	0.100E+02	0.250E+00	0.000E+00	0.000E+00	0.491E-01
BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
34	0.100E+02	0.250E+00	0.000E+00	0.000E+00	0.491E-01
BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
56	0.100E+02	0.500E+00	0.000E+00	0.000E+00	0.196E+00
BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
67	0.100E+02	0.500E+00	0.000E+00	0.000E+00	0.196E+00
BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
78	0.100E+02	0.500E+00	0.000E+00	0.000E+00	0.196E+00

SOLUTION

INTERNAL NODES

NODE	P(PSI)	TF(F)	Z	RHO (LBM/FT^3)	EM(LBM)	QUALITY
2	0.4185E+02	0.1000E+03	0.2025E-02	0.6200E+02	0.0000E+00	0.0000E+00
3	0.3370E+02	0.7180E+02	0.1709E-02	0.6229E+02	0.0000E+00	0.0000E+00
6	0.4163E+02	0.6002E+02	0.2157E-02	0.6237E+02	0.0000E+00	0.0000E+00
7	0.3327E+02	0.6451E+02	0.1709E-02	0.6235E+02	0.0000E+00	0.0000E+00

BRANCHES

BRANCH	KFACTOR (LBF-S^2/ (LBM-FT)^2)	DELP (PSI)	FLOW RATE (LBM/SEC)	VELOCITY (FT/SEC)	REYN. NO.	MACH NO.	ENTROPY GEN. BTU/(R-SEC)	LOST WORK LBF-FT/SEC
12	0.150E+04	0.815E+01	0.885E+00	0.419E+02	0.118E+06	0.333E-01	0.384E-04	0.167E+02
23	0.150E+04	0.815E+01	0.885E+00	0.419E+02	0.118E+06	0.333E-01	0.384E-04	0.167E+02
34	0.160E+04	0.870E+01	0.885E+00	0.417E+02	0.844E+05	0.343E-01	0.430E-04	0.178E+02
56	0.412E+02	0.837E+01	0.541E+01	0.636E+02	0.219E+06	0.530E-01	0.258E-03	0.104E+03
67	0.412E+02	0.837E+01	0.541E+01	0.636E+02	0.219E+06	0.530E-01	0.258E-03	0.104E+03
78	0.407E+02	0.827E+01	0.541E+01	0.637E+02	0.234E+06	0.528E-01	0.253E-03	0.103E+03

***** TOTAL ENTROPY GENERATION = 0.890E-03 BTU/(R-SEC) ******

**** TOTAL WORK LOST = 0.661E+00 HP *****

TIME OF ANALYSIS WAS 2.002880000000000E-002 SECS

APPENDIX I—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 6

Radial Flow on a Rotating Disk

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
Paul Schallhorn
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex6\Ex6.dat
OUTPUT FILE NAME
Ex6.out
TITLE
Radial Flow on a Rotating Radial Disk
USETUP
F
DENCON      GRAVITY     ENERGY      MIXTURE     THRUST      STEADY      TRANSV      SAVER
F           F           T           F           F           T           F           F
HEX         HCOEF       REACTING    INERTIA     CONDX       ADDPROP     PRINTI      ROTATION
F           F           F           T           F           F           T           T
BUOYANCY    HRATE       INVAL       MSORCE      MOVBND      TPA         VARGEO      TVM
F           T           F           F           F           F           F           F
SHEAR       PRNTIN      PRNTADD     OPVALVE     TRANSQ      CONJUG      RADIAT      WINPLOT
F           F           F           F           F           F           F           T
PRESS       INSUC       VARROT      CYCLIC      CHKVALS     WINFILE     DALTON
F           F           F           F           F           T           F
NORMAL      SIMUL       SECONDL     NRSOLVT
F           T           F           F
NNODES      NINT        NBR         NF
 13         11          12          1
RELAXK      RELAXD      RELAXH      CC          NITER
 1          0.5         1           0.0001      500
NFLUID(I), I = 1, NF
 11
NODE        INDEX         DESCRIPTION
 1          2             "Node 1"
 2          1             "Node 2"
 3          1             "Node 3"
 4          1             "Node 4"
 5          1             "Node 5"
 6          1             "Node 6"
 7          1             "Node 7"
 8          1             "Node 8"
 9          1             "Node 9"
 10         1             "Node 10"
 11         1             "Node 11"
 12         1             "Node 12"
 13         2             "Node 13"

NODE     PRES (PSI)    TEMP(DEGF)     MASS SOURC     HEAT SOURC     THRST AREA     CONCENTRATION
 1       90            80             0              0              0
 2       14.7          70             0              0              0
 3       14.7          70             0              0              0
 4       14.7          70             0              0              0
 5       14.7          70             0              0              0
 6       14.7          70             0              0              0
 7       14.7          70             0              0              0
 8       14.7          70             0              0              0
 9       14.7          70             0              0              0
 10      14.7          70             0              0              0
 11      14.7          70             0              0              0
 12      14.7          70             0              0              0
 13      30            80             0              0              0
```

```
INODE    NUMBR     NAMEBR
 2       2         12      23
 3       2         23      34
 4       2         34      45
 5       2         45      56
 6       2         56      67
 7       2         67      78
 8       2         78      89
 9       2         89      910
 10      2         910     1011
 11      2         1011    1112
 12      2         1112    1213
BRANCH  UPNODE  DNNODE  OPTION  DESCRIPTION
12      1       2       2       "Restrict 12"
23      2       3       2       "Restrict 23"
34      3       4       2       "Restrict 34"
45      4       5       2       "Restrict 45"
56      5       6       2       "Restrict 56"
67      6       7       2       "Restrict 67"
78      7       8       2       "Restrict 78"
89      8       9       2       "Restrict 89"
910     9       10      2       "Restrict 910"
1011    10      11      2       "Restrict 1011"
1112    11      12      2       "Restrict 1112"
1213    12      13      2       "Restrict 1213"
BRANCH    OPTION -2     FLOW COEFF    AREA
 12                     0             3.1416
BRANCH    OPTION -2     FLOW COEFF    AREA
 23                     0             1.8041
BRANCH    OPTION -2     FLOW COEFF    AREA
 34                     0             3.2218
BRANCH    OPTION -2     FLOW COEFF    AREA
 45                     0             4.6767
BRANCH    OPTION -2     FLOW COEFF    AREA
 56                     0             5.7231
BRANCH    OPTION -2     FLOW COEFF    AREA
 67                     0             6.2062
BRANCH    OPTION -2     FLOW COEFF    AREA
 78                     0             68.33
BRANCH    OPTION -2     FLOW COEFF    AREA
 89                     0             6.2062
BRANCH    OPTION -2     FLOW COEFF    AREA
 910                    0             5.7231
BRANCH    OPTION -2     FLOW COEFF    AREA
 1011                   0             4.6767
BRANCH    OPTION -2     FLOW COEFF    AREA
 1112                   0             3.4605
BRANCH    OPTION -2     FLOW COEFF    AREA
 1213                   0.02189       6.2299
BRANCH        NOUBR       NMUBR
 12           0
 23           1           12
 34           1           23
 45           1           34
 56           1           45
 67           1           56
 78           1           67
 89           1           78
 910          1           89
 1011         1           910
 1112         1           1011
 1213         1           1112
```

```
BRANCH        NODBR       NMDBR
 12           1           23
 23           1           34
 34           1           45
 45           1           56
 56           1           67
 67           1           78
 78           1           89
 89           1           910
 910          1           1011
 1011         1           1112
 1112         1           1213
 1213         0

BRANCH
 12
UPSTRM BR.     ANGLE
DNSTRM BR.     ANGLE
 23            0.00000
BRANCH
 23
 UPSTRM BR.    ANGLE
 12            0.00000
 DNSTRM BR.    ANGLE
 34            0.00000
BRANCH
 34
 UPSTRM BR.    ANGLE
 23            0.00000
 DNSTRM BR.    ANGLE
 45            0.00000
BRANCH
 45
 UPSTRM BR.    ANGLE
 34            0.00000
 DNSTRM BR.    ANGLE
 56            0.00000
BRANCH
 56
 UPSTRM BR.    ANGLE
 45            0.00000
 DNSTRM BR.    ANGLE
 67            0.00000
BRANCH
 67
 UPSTRM BR.    ANGLE
 56            0.00000
 DNSTRM BR.    ANGLE
 78            0.00000
BRANCH
 78
 UPSTRM BR.    ANGLE
 67            0.00000
 DNSTRM BR.    ANGLE
 89            0.00000
BRANCH
 89
 UPSTRM BR.    ANGLE
 78            0.00000
 DNSTRM BR.    ANGLE
 910           0.00000
BRANCH
 910
 UPSTRM BR.    ANGLE
 89            0.00000
 DNSTRM BR.    ANGLE
 1011          0.00000
```

```
BRANCH
 1011
 UPSTRM BR.    ANGLE
 910           0.00000
 DNSTRM BR.    ANGLE
 1112          0.00000
BRANCH
 1112
 UPSTRM BR.    ANGLE
 1011          0.00000
 DNSTRM BR.    ANGLE
 1213          0.00000
BRANCH
 1213
 UPSTRM BR.    ANGLE
 1112          0.00000
 DNSTRM BR.    ANGLE
NUMBER OF BRANCHES WITH INERTIA
 12
 12
 23
 34
 45
 56
 67
 78
 89
 910
 1011
 1112
 1213
NUMBER OF ROTATING BRANCHES
 9
BRANCH     UPST RAD     DNST RAD     RPM       K ROT
 23        1.25         2.25         5000      0.8671
 34        2.25         3.625        5000      0.8158
 45        3.625        4.6875       5000      0.763
 56        4.6875       5.375        5000      0.7252
 67        5.375        5.5          5000      0.7076
 89        5.5          5.375        5000      0.7129
 910       5.375        4.6875       5000      0.7349
 1011      4.6875       3.625        5000      0.7824
 1112      3.625        2.65         5000      0.8376
```

```
                G F S S P (Version 5.0)
        Generalized Fluid System Simulation Program
                    September, 2006
      Developed by NASA/Marshall Space Flight Center
        Copyright © by Marshall Space Flight Center

    A generalized computer program to calculate flow
    rates, pressures, temperatures and concentrations
    in a flow network.
```

```
TITLE     :Radial Flow on a Rotating Radial Disk
ANALYST   :Paul Schallhorn
FILEIN    :C:\Program Files\GFSSP\Examples\Ex6\Ex6.dat
FILEOUT   :Ex6.out
LOGICAL VARIABLES
 DENCON   = F
 GRAVITY  = F
 ENERGY   = T
 MIXTURE  = F
 THRUST   = F
 STEADY   = T
 TRANSV   = F
 SAVER    = F
 HEX      = F
 HCOEF    = F
 REACTING = F
 INERTIA  = T
 CONDX    = F
 TWOD     = F
 PRINTI   = T
 ROTATION = T
 BUOYANCY = F
 HRATE    = T
 INVAL    = F
 MSORCE   = F
 MOVBND   = F
 TPA      = F
 VARGEO   = F
 TVM      = F
 SHEAR    = F
 PRNTIN   = F
 PRNTADD  = F
 ADDPROP  = F
 PRESS    = F
 INSUC    = F
 VARROT   = F
 NORMAL   = F
 SECONDL  = F
 CONJUG   = F
 NRSOLVT  = F

 NNODES   = 13
 NINT     = 11
 NBR      = 12
 NF       = 1
 NVAR     = 23
 NHREF    = 2

FLUIDS: H2O
BOUNDARY NODES
 NODE      P              T              RHO            AREA
           (PSI)          (F)            (LBM/FT^3)     (IN^2)
 1         0.9000E+02     0.8000E+02     0.6224E+02     0.0000E+00
 13        0.3000E+02     0.8000E+02     0.6222E+02     0.0000E+00
```

SOLUTION
INTERNAL NODES

NODE	P(PSI)	TF(F)	Z	RHO (LBM/FT^3)	EM(LBM)	QUALITY
2	0.9000E+02	0.8000E+02	0.4500E-02	0.6224E+02	0.0000E+00	0.0000E+00
3	0.1237E+03	0.8001E+02	0.6182E-02	0.6225E+02	0.0000E+00	0.0000E+00
4	0.1924E+03	0.8002E+02	0.9618E-02	0.6226E+02	0.0000E+00	0.0000E+00
5	0.2582E+03	0.8004E+02	0.1290E-01	0.6227E+02	0.0000E+00	0.0000E+00
6	0.3048E+03	0.8005E+02	0.1523E-01	0.6228E+02	0.0000E+00	0.0000E+00
7	0.3135E+03	0.8005E+02	0.1566E-01	0.6228E+02	0.0000E+00	0.0000E+00
8	0.3135E+03	0.8005E+02	0.1566E-01	0.6228E+02	0.0000E+00	0.0000E+00
9	0.3046E+03	0.8005E+02	0.1522E-01	0.6228E+02	0.0000E+00	0.0000E+00
10	0.2568E+03	0.8004E+02	0.1283E-01	0.6227E+02	0.0000E+00	0.0000E+00
11	0.1877E+03	0.8002E+02	0.9379E-02	0.6226E+02	0.0000E+00	0.0000E+00
12	0.1328E+03	0.8001E+02	0.6637E-02	0.6225E+02	0.0000E+00	0.0000E+00

BRANCHES

BRANCH	KFACTOR (LBF-S^2/ (LBM-FT)^2)	DELP (PSI)	FLOW RATE (LBM/SEC)	VELOCITY (FT/SEC)	REYN. NO.	MACH NO.	ENTROPY GEN. BTU/(R-SEC)	LOST WORK LBF-FT/SEC
12	0.000E+00	0.850E-11	0.729E+01	0.537E+01	0.965E+05	0.437E-02	0.000E+00	0.000E+00
23	0.000E+00	-0.337E+02	0.729E+01	0.935E+01	0.127E+06	0.762E-02	0.000E+00	0.000E+00
34	0.000E+00	-0.688E+02	0.729E+01	0.524E+01	0.953E+05	0.426E-02	0.000E+00	0.000E+00
45	0.000E+00	-0.658E+02	0.729E+01	0.361E+01	0.792E+05	0.294E-02	0.000E+00	0.000E+00
56	0.000E+00	-0.466E+02	0.729E+01	0.295E+01	0.716E+05	0.240E-02	0.000E+00	0.000E+00
67	0.000E+00	-0.871E+01	0.729E+01	0.272E+01	0.688E+05	0.221E-02	0.000E+00	0.000E+00
78	0.000E+00	0.854E-11	0.729E+01	0.247E+00	0.207E+05	0.201E-03	0.000E+00	0.000E+00
89	0.000E+00	0.884E+01	0.729E+01	0.272E+01	0.688E+05	0.221E-02	0.000E+00	0.000E+00
910	0.000E+00	0.478E+02	0.729E+01	0.295E+01	0.716E+05	0.240E-02	0.000E+00	0.000E+00
1011	0.000E+00	0.692E+02	0.729E+01	0.361E+01	0.792E+05	0.294E-02	0.000E+00	0.000E+00
1112	0.000E+00	0.549E+02	0.729E+01	0.487E+01	0.920E+05	0.397E-02	0.000E+00	0.000E+00
1213	0.278E+03	0.103E+03	0.729E+01	0.271E+01	0.686E+05	0.221E-02	0.413E-02	0.173E+04

SOLUTION SATISFIED CONVERGENCE CRITERION OF 0.100E-03 IN 6 ITERATIONS
TAU = 100000000.000000 ISTEP = 1

TIME OF ANALYSIS WAS 3.004320000000000E-002 SECS

APPENDIX J—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 7

Flow in a Long Bearing Squeeze Film Damper

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
Paul Schallhorn
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex7\Ex7.dat
OUTPUT FILE NAME
Ex7.out
TITLE
Flow in a Long Bearing Squeeze Film Damper
USETUP
F
DENCON     GRAVITY    ENERGY     MIXTURE     THRUST     STEADY      TRANSV    SAVER
T          F          F          F           F          T           F         F
HEX        HCOEF      REACTING   INERTIA     CONDX       ADDPROP    PRINTI    ROTATION
F          F          F          F           F          F           F         F
BUOYANCY   HRATE      INVAL      MSORCE      MOVBND     TPA         VARGEO    TVM
F          T          F          F           T          F           F         F
SHEAR      PRNTIN     PRNTADD    OPVALVE     TRANSQ     CONJUG      RADIAT    WINPLOT
F          F          T          F           F          F           F         F
PRESS      INSUC      VARROT     CYCLIC      CHKVALS    WINFILE     DALTON
F          F          F          F           F          T           F
NORMAL     SIMUL       SECONDL   NRSOLVT
F          T          T          F
NNODES     NINT        NBR       NF
 20        18         19         0
RELAXK     RELAXD     RELAXH     CC          NITER
 1         0.5        1          0.0001      500
RHOREF     EMUREF
 57.806    0.005932
NODE       INDEX      DESCRIPTION
 1         2          "Node 1"
 2         1          "Node 2"
 3         1          "Node 3"
 4         1          "Node 4"
 5         1          "Node 5"
 6         1          "Node 6"
 7         1          "Node 7"
 8         1          "Node 8"
 9         1          "Node 9"
 10        1          "Node 10"
 11        1          "Node 11"
 12        1          "Node 12"
 13        1          "Node 13"
 14        1          "Node 14"
 15        1          "Node 15"
 16        1          "Node 16"
 17        1          "Node 17"
 18        1          "Node 18"
 19        1          "Node 19"
 20        2          "Node 20"
NODE     PRES (PSI)   MASS SOURC     HEAT SOURC     THRST AREA
 1       0            0              0              0
 2       0            0              0              0
 3       0            0              0              0
 4       0            0              0              0
 5       0            0              0              0
 6       0            0              0              0
 7       0            0              0              0
 8       0            0              0              0
 9       0            0              0              0
 10      10           0              0              0
 11      0            0              0              0
 12      0            0              0              0
 13      0            0              0              0
 14      0            0              0              0
 15      0            0              0              0
 16      0            0              0              0
 17      0            0              0              0
```

```
 18      0             0              0              0
 19      0             0              0              0
 20      0             0              0              0
INODE       NUMBR      NAMEBR
 2          2          12         23
 3          2          23         34
 4          2          34         45
 5          2          45         56
 6          2          56         67
 7          2          67         78
 8          2          78         89
 9          2          89         910
 10         2          910        1011
 11         2          1011       1112
 12         2          1112       1213
 13         2          1213       1314
 14         2          1314       1415
 15         2          1415       1516
 16         2          1516       1617
 17         2          1617       1718
 18         2          1718       1819
 19         2          1819       1920
BRANCH      UPNODE      DNNODE       OPTION      DESCRIPTION
 12         1           2            3           "Duct 12"
 23         2           3            3           "Duct 23"
 34         3           4            3           "Duct 34"
 45         4           5            3           "Duct 45"
 56         5           6            3           "Duct 56"
 67         6           7            3           "Duct 67"
 78         7           8            3           "Duct 78"
 89         8           9            3           "Duct 89"
 910        9           10           3           "Duct 910"
 1011       10          11           3           "Duct 1011"
 1112       11          12           3           "Duct 1112"
 1213       12          13           3           "Duct 1213"
 1314       13          14           3           "Duct 1314"
 1415       14          15           3           "Duct 1415"
 1516       15          16           3           "Duct 1516"
 1617       16          17           3           "Duct 1617"
 1718       17          18           3           "Duct 1718"
 1819       18          19           3           "Duct 1819"
 1920       19          20           3           "Duct 1920"
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 12                    0.82673      0.01258     0.94       1         0.0118252
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 23                    0.8267       0.01799     0.94       1         0.0169106
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 34                    0.82673      0.02822     0.94       1         0.0265268
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 45                    0.82673      0.04217     0.94       1         0.0396398
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 56                    0.82673      0.05832     0.94       1         0.0548208
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 67                    0.82673      0.07492     0.94       1         0.0704248
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 78                    0.82673      0.09018     0.94       1         0.0847692
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 89                    0.82673      0.10244     0.94       1         0.0962936
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 910                   0.82673      0.11037     0.94       1         0.103748
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 1011                  0.82673      0.11311     0.94       1         0.106323
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 1112                  0.82673      0.11037     0.94       1         0.103748
BRANCH   OPTION -3     LENGTH       HEIGHT      WIDTH      TYPE      AREA
 1213                  0.82673      0.10244     0.94       1         0.0962936
```

BRANCH	OPTION -3	LENGTH	HEIGHT	WIDTH	TYPE	AREA
1314		0.82673	0.09018	0.94	1	0.0847692
BRANCH	OPTION -3	LENGTH	HEIGHT	WIDTH	TYPE	AREA
1415		0.82673	0.07492	0.94	1	0.0704248
BRANCH	OPTION -3	LENGTH	HEIGHT	WIDTH	TYPE	AREA
1516		0.82673	0.05832	0.94	1	0.0548208
BRANCH	OPTION -3	LENGTH	HEIGHT	WIDTH	TYPE	AREA
1617		0.82673	0.04217	0.94	1	0.0396398
BRANCH	OPTION -3	LENGTH	HEIGHT	WIDTH	TYPE	AREA
1718		0.82673	0.02822	0.94	1	0.0265268
BRANCH	OPTION -3	LENGTH	HEIGHT	WIDTH	TYPE	AREA
1819		0.82673	0.01799	0.94	1	0.0169106
BRANCH	OPTION -3	LENGTH	HEIGHT	WIDTH	TYPE	AREA
1920		0.82673	0.01258	0.94	1	0.0118252

NUMBER OF NODES WITH MOVING BOUNDARY

18

NODE	AREAN	VBOUND
2	0.77713	0.25618
3	0.77713	0.4846
4	0.77713	0.6605
5	0.77713	0.76483
6	0.77713	0.78628
7	0.77713	0.72252
8	0.77713	0.58047
9	0.77713	0.37551
10	0.77713	0.12986
11	0.77713	-0.12986
12	0.77713	-0.37551
13	0.77713	-0.58047
14	0.77713	-0.72252
15	0.77713	-0.78628
16	0.77713	-0.76483
18	0.77713	-0.4846
19	0.77713	-0.25618

```
                G F S S P (Version 5.0)
        Generalized Fluid System Simulation Program
                     September, 2006
      Developed by NASA/Marshall Space Flight Center
        Copyright © by Marshall Space Flight Center

   A generalized computer program to calculate flow
   rates, pressures, temperatures and concentrations
   in a flow network.
```

```
TITLE     :Flow in a Long Bearing Squeeze Film Damper
ANALYST   :Paul Schallhorn
FILEIN    :C:\Program Files\GFSSP\Examples\Ex7\Ex7.dat
FILEOUT   :Ex7.out
 LOGICAL VARIABLES
DENCON    = T
GRAVITY   = F
ENERGY    = F
MIXTURE   = F
THRUST    = F
STEADY    = T
TRANSV    = F
SAVER     = F
HEX       = F
HCOEF     = F
REACTING  = F
INERTIA   = F
CONDX     = F
TWOD      = F
PRINTI    = F
ROTATION  = F
BUOYANCY  = F
HRATE     = T
INVAL     = F
MSORCE    = F
MOVBND    = T
TPA       = F
VARGEO    = F
TVM       = F
SHEAR     = F
PRNTIN    = F
PRNTADD   = T
ADDPROP   = F
PRESS     = F
INSUC     = F
VARROT    = F
NORMAL    = F
SECONDL   = T
CONJUG    = F
NRSOLVT   = F

NNODES    = 20
NINT      = 18
NBR       = 19
NF        = 0
NVAR      = 37
NHREF     = 2
RHOREF    = 57.8060 LBM/FT**3
EMUREF    = 0.5932E-02 LBM/FT-SEC
BOUNDARY NODES
NODE        P             AREA
  (PSI)     (IN^2)
  1         0.0000E+00    0.0000E+00
  20        0.0000E+00    0.0000E+00
```

SOLUTION

INTERNAL NODES

NODE	P(PSI)	EM(LBM)
2	0.1365E+02	0.0000E+00
3	0.1273E+02	0.0000E+00
4	0.9716E+01	0.0000E+00
5	0.7660E+01	0.0000E+00
6	0.5812E+01	0.0000E+00
7	0.4250E+01	0.0000E+00
8	0.2901E+01	0.0000E+00
9	0.1690E+01	0.0000E+00
10	0.5551E+00	0.0000E+00
11	-0.5551E+00	0.0000E+00
12	-0.1690E+01	0.0000E+00
13	-0.2901E+01	0.0000E+00
14	-0.4250E+01	0.0000E+00
15	-0.5812E+01	0.0000E+00
16	-0.7660E+01	0.0000E+00
17	-0.9716E+01	0.0000E+00
18	-0.1273E+02	0.0000E+00
19	-0.1365E+02	0.0000E+00

BRANCHES

BRANCH	KFACTOR (LBF-S^2/ (LBM-FT)^2)	DELP (PSI)	FLOW RATE (LBM/SEC)	VELOCITY (FT/SEC)	REYN. NO.	MACH NO.	ENTROPY GEN. BTU/(R-SEC)	LOST WORK LBF-FT/SEC
12	0.440E+06	-0.136E+02	-0.668E-01	-0.141E+02	0.140E+04	0.000E+00	0.635E-05	0.227E+01
23	0.770E+06	0.920E+00	0.131E-01	0.193E+01	0.230E+03	0.000E+00	0.841E-07	0.301E-01
34	0.161E+05	0.301E+01	0.164E+00	0.154E+02	0.230E+04	0.000E+00	0.345E-05	0.123E+01
45	0.216E+04	0.206E+01	0.370E+00	0.233E+02	0.425E+04	0.000E+00	0.530E-05	0.190E+01
56	0.718E+03	0.185E+01	0.609E+00	0.277E+02	0.594E+04	0.000E+00	0.784E-05	0.280E+01
67	0.308E+03	0.156E+01	0.854E+00	0.302E+02	0.735E+04	0.000E+00	0.929E-05	0.332E+01
78	0.167E+03	0.135E+01	0.108E+01	0.317E+02	0.846E+04	0.000E+00	0.101E-04	0.363E+01
89	0.110E+03	0.121E+01	0.126E+01	0.326E+02	0.927E+04	0.000E+00	0.106E-04	0.380E+01
910	0.861E+02	0.113E+01	0.138E+01	0.331E+02	0.976E+04	0.000E+00	0.109E-04	0.389E+01
1011	0.795E+02	0.111E+01	0.142E+01	0.332E+02	0.993E+04	0.000E+00	0.110E-04	0.392E+01
1112	0.861E+02	0.113E+01	0.138E+01	0.331E+02	0.976E+04	0.000E+00	0.109E-04	0.389E+01
1213	0.110E+03	0.121E+01	0.126E+01	0.326E+02	0.927E+04	0.000E+00	0.106E-04	0.380E+01
1314	0.167E+03	0.135E+01	0.108E+01	0.317E+02	0.846E+04	0.000E+00	0.101E-04	0.363E+01
1415	0.308E+03	0.156E+01	0.854E+00	0.302E+02	0.735E+04	0.000E+00	0.929E-05	0.332E+01
1516	0.718E+03	0.185E+01	0.609E+00	0.277E+02	0.594E+04	0.000E+00	0.784E-05	0.280E+01
1617	0.216E+04	0.206E+01	0.370E+00	0.233E+02	0.425E+04	0.000E+00	0.530E-05	0.190E+01
1718	0.161E+05	0.301E+01	0.164E+00	0.154E+02	0.230E+04	0.000E+00	0.345E-05	0.123E+01
1819	0.770E+06	0.920E+00	0.131E-01	0.193E+01	0.230E+03	0.000E+00	0.841E-07	0.301E-01
1920	0.440E+06	-0.136E+02	-0.668E-01	-0.141E+02	0.140E+04	0.000E+00	0.635E-05	0.227E+01

***** TOTAL ENTROPY GENERATION = 0.139E-03 BTU/(R-SEC) ******

**** TOTAL WORK LOST = 0.903E-01 HP *****

TIME OF ANALYSIS WAS 1.001440000000000E-002 SECS

APPENDIX K—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 8

Simulation of the Blow Down of a Pressurized Tank

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
Alok Majumdar
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex8\Ex8.dat
OUTPUT FILE NAME
Ex8.out
TITLE
Simulation of the Blow Down of a Pressurized Tank
USETUP
F
DENCON    GRAVITY   ENERGY      MIXTURE    THRUST    STEADY     TRANSV    SAVER
F         F         T           F          F         F          T         F
HEX       HCOEF     REACTING    INERTIA    CONDX     ADDPROP    PRINTI    ROTATION
F         F         F           F          F         T          T         F
BUOYANCY  HRATE     INVAL       MSORCE     MOVBND    TPA        VARGEO    TVM
F         F         F           F          F         F          F         F
SHEAR     PRNTIN    PRNTADD     OPVALVE    TRANSQ    CONJUG     RADIAT    WINPLOT
F         T         T           F          F         F          F         T
PRESS     INSUC     VARROT      CYCLIC     CHKVALS   WINFILE    DALTON
F         F         F           F          F         T          F
NORMAL    SIMUL     SECONDL     NRSOLVT
F         T         T           F
NNODES    NINT      NBR         NF
 2        1         1           1
RELAXK    RELAXD    RELAXH      CC         NITER
 1        0.5       1           0.0001     500
DTAU      TIMEF     TIMEL       NPSTEP     NPWSTEP
 1        0         200         25         1
NFLUID(I), I = 1, NF
 33
RREF      CPREF     GAMREF      EMUREF     AKREF          PREF     TREF     HREF     SREF
 53.34    0.24      1.3999      1.26e-05   4.133e-06      14.7     -459     0        0
NODE      INDEX     DESCRIPTION
 1        1         "Node 1"
 2        2         "Node 2"
NODE      PRES (PSI)    TEMP(DEGF)  MASS     SOURC    HEAT SOURC   THRST AREA NODE-VOLUME CONCENTRATION
 1        100            80         0        0        0            17280
 ex8hs2.dat
INODE     NUMBR     NAMEBR
 1        1         12
BRANCH    UPNODE    DNNODE     OPTION     DESCRIPTION
 12       1         2          22         "Orifice 12"
BRANCH    OPTION -22     AREA          FLOW COEF
 12                      0.00785       1
INITIAL FLOWRATES IN BRANCHES FOR UNSTEADY FLOW
 12 0
```

EXAMPLE 8 HISTORY FILE

```
EX8HS2.DAT
2
0       14.700   80.00 1.00
1000    14.700   80.00 1.00
```

```
        G F S S P (Version 5.0)
        Generalized Fluid System Simulation Program
                September, 2006
        Developed by NASA/Marshall Space Flight Center
        Copyright © by Marshall Space Flight Center

    A generalized computer program to calculate flow
    rates, pressures, temperatures and concentrations
    in a flow network.
```

```
TITLE     :Simulation of the Blow Down of a Pressurized Tank
ANALYST   :Alok Majumdar
FILEIN    :C:\Program Files\GFSSP\Examples\Ex8\Ex8.dat
FILEOUT   :Ex8.out

  LOGICAL VARIABLES
DENCON   = F
GRAVITY  = F
ENERGY   = T
MIXTURE = F
THRUST   = F
STEADY   = F
TRANSV   = T
SAVER    = F
HEX      = F
HCOEF    = F
REACTING = F
INERTIA  = F
CONDX    = F
TWOD     = F
PRINTI   = T
ROTATION = F
BUOYANCY = F
HRATE    = F
INVAL    = F
MSORCE   = F
MOVBND   = F
TPA      = F
VARGEO   = F
TVM      = F
SHEAR    = F
PRNTIN   = T
PRNTADD  = T
ADDPROP  = T
PRESS    = F
INSUC    = F
VARROT   = F
NORMAL   = F
SECONDL  = T
CONJUG   = F
NRSOLVT  = F

NNODES   = 2
NINT     = 1
NBR      = 1
NF       = 1
NVAR     = 3
NHREF    = 2

FLUIDS: IDEL
```

```
BOUNDARY NODES
 NODE      P              T              RHO             AREA
           (PSI)          (F)            (LBM/FT^3)      (IN^2)
 2         0.1470E+02     0.8000E+02     0.7355E-01      0.0000E+00
INPUT SPECIFICATIONS FOR INTERNAL NODES
 NODE     AREA            MASS          HEAT
          (IN^2)         (LBM/S)       (BTU/LBM)
  1       0.0000E+00     0.0000E+00    0.0000E+00
BRANCH    UPNODE       DNNODE         OPTION
 12       1            2              22
BRANCH OPTION -22     FLOW COEF      AREA
 12                   0.100E+01      0.785E-02
INITIAL GUESS FOR INTERNAL NODES
NODE      P(PSI)          TF(F)          Z(COMP)        RHO             QUALITY
                                                        (LBM/FT^3)
 1        0.1000E+03     0.8000E+02     0.1000E+01     0.5003E+00      0.0000E+00
TRIAL SOLUTION
BRANCH     DELP(PSI)     FLOWRATE(LBM/SEC)
 12         0.0000        0.0000

SOLUTION SATISFIED CONVERGENCE CRITERION OF  0.100E-03 IN   7 ITERATIONS
TAU =   1.00000000000000       ISTEP = 1
                :
                :
                :
                :
SOLUTION SATISFIED CONVERGENCE CRITERION OF  0.100E-03 IN   7 ITERATIONS
TAU =   24.0000000000000       ISTEP = 24

        ISTEP = 25      TAU = 0.25000E+02
BOUNDARY NODES
NODE    P(PSI)        TF(F)          Z(COMP)        RHO             QUALITY
                                                    (LBM/FT^3)
 2      0.1470E+02    0.8000E+02     0.1000E+01     0.7355E-01      0.0000E+00

SOLUTION
INTERNAL NODES
  NODE   P(PSI)        TF(F)          Z              RHO             EM(LBM)         QUALITY
                                                     (LBM/FT^3)
  1      0.8831E+02    0.6118E+02     0.1000E+01     0.4578E+00      0.4578E+01      0.0000E+00

  NODE   H             ENTROPY        EMU            COND            CP              GAMA
         BTU/LB        BTU/LB-R       LBM/FT-SEC     BTU/FT-S-R      BTU/LB-R

  1      0.1294E+03    0.1501E+01     0.1260E-04     0.4133E-05      0.2400E+00      0.1400E+01

BRANCHES
BRANCH   KFACTOR       DELP        FLOW RATE    VELOCITY    REYN. NO.   MACH NO.    ENTROPY GEN.   LOST WORK
         (LBF-S^2/     (PSI)       (LBM/SEC)    (FT/SEC)                            BTU/(R-SEC)    LBF-FT/SEC
         (LBM-FT)^2)
 12      0.000E+00     0.736E+02   0.162E-01    0.647E+03   0.196E+06   0.579E+00   0.000E+00      0.000E+00


         ***** TOTAL ENTROPY GENERATION =     0.000E+00 BTU/(R-SEC) ******

         **** TOTAL WORK LOST =       0.000E+00 HP *****


SOLUTION SATISFIED CONVERGENCE CRITERION OF  0.100E-03 IN   7 ITERATIONS
TAU =   25.0000000000000       ISTEP = 25

                :
                :
                :
                :
```

```
SOLUTION SATISFIED CONVERGENCE CRITERION OF  0.100E-03 IN   7 ITERATIONS
TAU =   99.0000000000000       ISTEP = 99

       ISTEP = 100     TAU = 0.10000E+03
BOUNDARY NODES
  NODE     P(PSI)         TF(F)          Z(COMP)       RHO            QUALITY
                                                      (LBM/FT^3)
  2        0.1470E+02     0.8000E+02     0.1000E+01    0.7355E-01     0.0000E+00
SOLUTION
INTERNAL NODES
NODE       P(PSI)         TF(F)          Z             RHO            EM(LBM)        QUALITY
                                                      (LBM/FT^3)
  1        0.6159E+02     0.1025E+02     0.1000E+01    0.3539E+00     0.3539E+01     0.0000E+00

NODE       H              ENTROPY        EMU           COND           CP             GAMA
           BTU/LB         BTU/LB-R       LBM/FT-SEC    BTU/FT-S-R     BTU/LB-R
  1        0.1294E+03     0.1501E+01     0.1260E-04    0.4133E-05     0.2400E+00       0.1400E+01

BRANCHES
BRANCH   KFACTOR       DELP        FLOW RATE    VELOCITY    REYN. NO.  MACH NO.     ENTROPY GEN.  LOST WORK
         (LBF-S^2/     (PSI)       (LBM/SEC)    (FT/SEC)                            BTU/(R-SEC)   LBF-FT/SEC
         (LBM-FT)^2)
  12     0.000E+00     0.469E+02   0.119E-01    0.615E+03   0.144E+06   0.579E+00    0.000E+00     0.000E+00

         ***** TOTAL ENTROPY GENERATION =     0.000E+00 BTU/(R-SEC) ******

         **** TOTAL WORK LOST =       0.000E+00 HP *****

SOLUTION SATISFIED CONVERGENCE CRITERION OF  0.100E-03 IN   7 ITERATIONS
TAU =   100.000000000000       ISTEP =  100
               :
               :
               :
               :

SOLUTION SATISFIED CONVERGENCE CRITERION OF  0.100E-03 IN   7 ITERATIONS
TAU =   199.000000000000       ISTEP =  199

       ISTEP = 200     TAU = 0.20000E+03
BOUNDARY NODES
 NODE       P(PSI)          TF(F)          Z(COMP)        RHO            QUALITY
                                                         (LBM/FT^3)
 2          0.1470E+02      0.8000E+02     0.1000E+01     0.7355E-01     0.0000E+00

SOLUTION
 INTERNAL NODES
 NODE       P(PSI)          TF(F)          Z              RHO             EM(LBM)       QUALITY
                                                         (LBM/FT^3)
  1         0.3914E+02      -0.4681E+02    0.1000E+01     0.2560E+00      0.2560E+01    0.0000E+00

 NODE       H               ENTROPY        EMU            COND            CP            GAMA
  BTU/LB    BTU/LB-R        LBM/FT-SEC     BTU/FT-S-R     BTU/LB-R
  1         0.1294E+03      0.1501E+01     0.1260E-04     0.4133E-05      0.2400E+00    0.1400E+01

BRANCHES
BRANCH    KFACTOR       DELP        FLOW RATE    VELOCITY    REYN. NO.    MACH NO.    ENTROPY GEN.  LOST WORK
          (LBF-S^2/     (PSI)       (LBM/SEC)    (FT/SEC)                             BTU/(R-SEC)   LBF-FT/SEC
          (LBM-FT)^2)
 12       0.000E+00     0.244E+02   0.804E-02    0.576E+03   0.976E+05    0.579E+00   0.000E+00     0.000E+00

         ***** TOTAL ENTROPY GENERATION =     0.000E+00 BTU/(R-SEC) ******

         **** TOTAL WORK LOST =       0.000E+00 HP *****

SOLUTION SATISFIED CONVERGENCE CRITERION OF  0.100E-03 IN   7 ITERATIONS
TAU =   200.000000000000       ISTEP =  200

TIME OF ANALYSIS WAS   0.260374400000000      SECS
```

APPENDIX L—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 9

A Reciprocating Piston-Cylinder

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
Paul Schallhorn
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex9\Ex9.dat
OUTPUT FILE NAME
Ex9.out
TITLE
A Reciprocating Piston-Cylinder
USETUP
F
DENCON      GRAVITY     ENERGY      MIXTURE     THRUST      STEADY      TRANSV      SAVER
F           F           T           F           F           F           T           F
HEX         HCOEF       REACTING    INERTIA     CONDX       ADDPROP     PRINTI      ROTATION
F           F           F           F           F           F           F           F
BUOYANCY    HRATE       INVAL       MSORCE      MOVBND      TPA         VARGEO      TVM
F           T           F           F           T           F           T           F
SHEAR       PRNTIN      PRNTADD     OPVALVE     TRANSQ      CONJUG      RADIAT      WINPLOT
F           F           T           F           F           F           F           T
PRESS       INSUC       VARROT      CYCLIC      CHKVALS     WINFILE     DALTON
F           F           F           F           F           F           F
NORMAL      SIMUL       SECONDL     NRSOLVT
F           T           T           F
NNODES      NINT        NBR         NF
 2          2           1           1
RELAXK      RELAXD      RELAXH      CC          NITER
 1          0.5         1           0.0001      500
DTAU        TIMEF       TIMEL       NPSTEP      NPWSTEP
 0.0001     0           0.05         1          1
NFLUID(I), I = 1, NF
 4
NODE      INDEX      DESCRIPTION
 1        1          "Node 1"
 2        1          "Node 2"
NODE     PRES (PSI)     TEMP(DEGF)    MASS SOURC     HEAT SOURC     THRST AREA     NODE-VOLUME    CONCENTRATION
 1       14.7           75            0              0              0              0
 2       14.7           75            0              0              0              0
ex9vg.dat
INODE    NUMBR     NAMEBR
 1       1         12
 2       1         12


BRANCH     UPNODE         DNNODE       OPTION      DESCRIPTION
12         1              2            1           "Pipe 12"
BRANCH     OPTION -1      LENGTH       DIA         EPSD              ANGLE       AREA
 12                       7            3           0                 0           7.0686
INITIAL FLOWRATES IN BRANCHES FOR UNSTEADY FLOW
 12     0
NUMBER OF NODES WITH MOVING BOUNDARY
2
NODE
 1
 2
```

VARIABLE GEOMETRY HISTORY FILE

41

0.000000	0.0000	0.0000	0.0000	0.0000
0.001250	0.0000	0.0000	0.0000	0.0000
0.002500	0.0000	0.0000	0.0000	0.0000
0.003750	0.0000	0.0000	0.0000	0.0000
0.005000	0.0000	0.0000	0.0000	0.0000
0.006250	0.0000	0.0000	0.0000	0.0000
0.007500	0.0000	0.0000	0.0000	0.0000
0.008750	0.0000	0.0000	0.0000	0.0000
0.010000	0.0000	0.0000	0.0000	0.0000
0.011250	0.0000	0.0000	0.0000	0.0000
0.012500	0.0000	0.0000	0.0000	0.0000
0.013750	0.0000	0.0000	0.0000	0.0000
0.015000	0.0000	0.0000	0.0000	0.0000
0.016250	0.0000	0.0000	0.0000	0.0000
0.017500	0.0000	0.0000	0.0000	0.0000
0.018750	0.0000	0.0000	0.0000	0.0000
0.020000	0.0000	0.0000	0.0000	0.0000
0.021250	0.0000	0.0000	0.0000	0.0000
0.022500	0.0000	0.0000	0.0000	0.0000
0.023750	0.0000	0.0000	0.0000	0.0000
0.025000	0.0000	0.0000	0.0000	0.0000
0.026250	0.0000	0.0000	0.0000	0.0000
0.027500	0.0000	0.0000	0.0000	0.0000
0.028750	0.0000	0.0000	0.0000	0.0000
0.030000	0.0000	0.0000	0.0000	0.0000
0.031250	0.0000	0.0000	0.0000	0.0000
0.032500	0.0000	0.0000	0.0000	0.0000
0.033750	0.0000	0.0000	0.0000	0.0000
0.035000	0.0000	0.0000	0.0000	0.0000
0.036250	0.0000	0.0000	0.0000	0.0000
0.037500	0.0000	0.0000	0.0000	0.0000
0.038750	0.0000	0.0000	0.0000	0.0000
0.040000	0.0000	0.0000	0.0000	0.0000
0.041250	0.0000	0.0000	0.0000	0.0000
0.042500	0.0000	0.0000	0.0000	0.0000
0.043750	0.0000	0.0000	0.0000	0.0000
0.045000	0.0000	0.0000	0.0000	0.0000
0.046250	0.0000	0.0000	0.0000	0.0000
0.047500	0.0000	0.0000	0.0000	0.0000
0.048750	0.0000	0.0000	0.0000	0.0000
0.050000	0.0000	0.0000	0.0000	0.0000

BRANCH VOLUME

0.000000	49.48004	0.0000	100.000	0.0000
0.001250	49.21895	0.0000	100.000	0.0000
0.002500	48.44213	0.0000	100.000	0.0000
0.003750	47.16871	0.0000	100.000	0.0000
0.005000	45.43005	0.0000	100.000	0.0000
0.006250	43.26896	0.0000	100.000	0.0000
0.007500	40.73865	0.0000	100.000	0.0000
0.008750	37.90143	0.0000	100.000	0.0000
0.010000	34.82716	0.0000	100.000	0.0000
0.011250	31.59153	0.0000	100.000	0.0000
0.012500	28.27423	0.0000	100.000	0.0000
0.013750	24.95692	0.0000	100.000	0.0000
0.015000	21.72130	0.0000	100.000	0.0000
0.016250	18.64704	0.0000	100.000	0.0000
0.017500	15.80983	0.0000	100.000	0.0000
0.018750	13.27954	0.0000	100.000	0.0000
0.020000	11.11847	0.0000	100.000	0.0000
0.021250	9.379835	0.0000	100.000	0.0000
0.022500	8.106441	0.0000	100.000	0.0000
0.023750	7.329646	0.0000	100.000	0.0000
0.025000	7.068578	0.0000	100.000	0.0000
0.026250	7.329646	0.0000	100.000	0.0000
0.027500	8.106441	0.0000	100.000	0.0000
0.028750	9.379835	0.0000	100.000	0.0000
0.030000	11.11847	0.0000	100.000	0.0000
0.031250	13.27954	0.0000	100.000	0.0000
0.032500	15.80983	0.0000	100.000	0.0000

```
0.033750       18.64704      0.0000        100.000       0.0000
0.035000       21.72130      0.0000        100.000       0.0000
0.036250       24.95692      0.0000        100.000       0.0000
0.037500       28.27423      0.0000        100.000       0.0000
0.038750       31.59153      0.0000        100.000       0.0000
0.040000       34.82716      0.0000        100.000       0.0000
0.041250       37.90143      0.0000        100.000       0.0000
0.042500       40.73865      0.0000        100.000       0.0000
0.043750       43.26896      0.0000        100.000       0.0000
0.045000       45.43005      0.0000        100.000       0.0000
0.046250       47.16871      0.0000        100.000       0.0000
0.047500       48.44213      0.0000        100.000       0.0000
0.048750       49.21895      0.0000        100.000       0.0000
0.050000       49.48004      0.0000        100.000       0.0000
BRANCH         AREA
0.000000       7.06858347    1.0000        1.0000        1.0000
0.001250       7.06858347    1.0000        1.0000        1.0000
0.002500       7.06858347    1.0000        1.0000        1.0000
0.003750       7.06858347    1.0000        1.0000        1.0000
0.005000       7.06858347    1.0000        1.0000        1.0000
0.006250       7.06858347    1.0000        1.0000        1.0000
0.007500       7.06858347    1.0000        1.0000        1.0000
0.008750       7.06858347    1.0000        1.0000        1.0000
0.010000       7.06858347    1.0000        1.0000        1.0000
0.011250       7.06858347    1.0000        1.0000        1.0000
0.012500       7.06858347    1.0000        1.0000        1.0000
0.013750       7.06858347    1.0000        1.0000        1.0000
0.015000       7.06858347    1.0000        1.0000        1.0000
0.016250       7.06858347    1.0000        1.0000        1.0000
0.017500       7.06858347    1.0000        1.0000        1.0000
0.018750       7.06858347    1.0000        1.0000        1.0000
0.020000       7.06858347    1.0000        1.0000        1.0000
0.021250       7.06858347    1.0000        1.0000        1.0000
0.022500       7.06858347    1.0000        1.0000        1.0000
0.023750       7.06858347    1.0000        1.0000        1.0000
0.025000       7.06858347    1.0000        1.0000        1.0000
0.026250       7.06858347    1.0000        1.0000        1.0000
0.027500       7.06858347    1.0000        1.0000        1.0000
0.028750       7.06858347    1.0000        1.0000        1.0000
0.030000       7.06858347    1.0000        1.0000        1.0000
0.031250       7.06858347    1.0000        1.0000        1.0000
0.032500       7.06858347    1.0000        1.0000        1.0000
0.033750       7.06858347    1.0000        1.0000        1.0000
0.035000       7.06858347    1.0000        1.0000        1.0000
0.036250       7.06858347    1.0000        1.0000        1.0000
0.037500       7.06858347    1.0000        1.0000        1.0000
0.038750       7.06858347    1.0000        1.0000        1.0000
0.040000       7.06858347    1.0000        1.0000        1.0000
0.041250       7.06858347    1.0000        1.0000        1.0000
0.042500       7.06858347    1.0000        1.0000        1.0000
0.043750       7.06858347    1.0000        1.0000        1.0000
0.045000       7.06858347    1.0000        1.0000        1.0000
0.046250       7.06858347    1.0000        1.0000        1.0000
0.047500       7.06858347    1.0000        1.0000        1.0000
0.048750       7.06858347    1.0000        1.0000        1.0000
0.050000       7.06858347    1.0000        1.0000        1.0000
1
0.000000       7.06858347     0.000000
0.001250       7.06858347     2.457263
0.002500       7.06858347     4.854020
0.003750       7.06858347     7.131254
0.005000       7.06858347     9.232895
0.006250       7.06858347     11.10719
0.007500       7.06858347     12.70799
0.008750       7.06858347     13.99588
0.010000       7.06858347     14.93914
0.011250       7.06858347     15.51456
0.012500       7.06858347     15.70795
0.013750       7.06858347     15.51456
0.015000       7.06858347     14.93916
0.016250       7.06858347     13.99590
```

```
0.017500      7.06858347     12.70802
0.018750      7.06858347     11.10722
0.020000      7.06858347     9.232928
0.021250      7.06858347     7.131292
0.022500      7.06858347     4.854059
0.023750      7.06858347     2.457304
0.025000      7.06858347     0.000000
0.026250      7.06858347    -2.457222
0.027500      7.06858347    -4.853980
0.028750      7.06858347    -7.131217
0.030000      7.06858347    -9.232861
0.031250      7.06858347    -11.10716
0.032500      7.06858347    -12.70797
0.033750      7.06858347    -13.99586
0.035000      7.06858347    -14.93913
0.036250      7.06858347    -15.51455
0.037500      7.06858347    -15.70795
0.038750      7.06858347    -15.51457
0.040000      7.06858347    -14.93917
0.041250      7.06858347    -13.99592
0.042500      7.06858347    -12.70804
0.043750      7.06858347    -11.10725
0.045000      7.06858347    -9.232962
0.046250      7.06858347    -7.131329
0.047500      7.06858347    -4.854099
0.048750      7.06858347    -2.457345
0.050000      7.06858347     0.000000
2
0.000000      7.06858347     0.000000
0.001250      7.06858347     2.457263
0.002500      7.06858347     4.854020
0.003750      7.06858347     7.131254
0.005000      7.06858347     9.232895
0.006250      7.06858347     11.10719
0.007500      7.06858347     12.70799
0.008750      7.06858347     13.99588
0.010000      7.06858347     14.93914
0.011250      7.06858347     15.51456
0.012500      7.06858347     15.70795
0.013750      7.06858347     15.51456
0.015000      7.06858347     14.93916
0.016250      7.06858347     13.99590
0.017500      7.06858347     12.70802
0.018750      7.06858347     11.10722
0.020000      7.06858347     9.232928
0.021250      7.06858347     7.131292
0.022500      7.06858347     4.854059
0.023750      7.06858347     2.457304
0.025000      7.06858347     0.000000
0.026250      7.06858347    -2.457222
0.027500      7.06858347    -4.853980
0.028750      7.06858347    -7.131217
0.030000      7.06858347    -9.232861
0.031250      7.06858347    -11.10716
0.032500      7.06858347    -12.70797
0.033750      7.06858347    -13.99586
0.035000      7.06858347    -14.93913
0.036250      7.06858347    -15.51455
0.037500      7.06858347    -15.70795
0.038750      7.06858347    -15.51457
0.040000      7.06858347    -14.93917
0.041250      7.06858347    -13.99592
0.042500      7.06858347    -12.70804
0.043750      7.06858347    -11.10725
0.045000      7.06858347    -9.232962
0.046250      7.06858347    -7.131329
0.047500      7.06858347    -4.854099
0.048750      7.06858347    -2.457345
0.050000      7.06858347     0.000000
```

```
                G F S S P (Version 5.0)
       Generalized Fluid System Simulation Program
                    September, 2006
     Developed by NASA/Marshall Space Flight Center
       Copyright © by Marshall Space Flight Center

    A generalized computer program to calculate flow
    rates, pressures, temperatures and concentrations
    in a flow network.
```

```
 TITLE   :A Reciprocating Piston-Cylinder
 ANALYST :Paul Schallhorn
 FILEIN  :C:\Program Files\GFSSP\Examples\Ex9\Ex9.dat
 FILEOUT :Ex9.out
 LOGICAL VARIABLES
  DENCON    = F
  GRAVITY   = F
  ENERGY    = T
  MIXTURE   = F
  THRUST    = F
  STEADY    = F
  TRANSV    = T
  SAVER     = F
  HEX       = F
  HCOEF     = F
  REACTING  = F
  INERTIA   = F
  CONDX     = F
  TWOD      = F
  PRINTI    = F
  ROTATION  = F
  BUOYANCY  = F
  HRATE     = T
  INVAL     = F
  MSORCE    = F
  MOVBND    = T
  TPA       = F
  VARGEO    = T
  TVM       = F
  SHEAR     = F
  PRNTIN    = F
  PRNTADD   = T
  ADDPROP   = F
  PRESS     = F
  INSUC     = F
  VARROT    = F
  NORMAL    = F
  SECONDL   = T
  CONJUG    = F
  NRSOLVT   = F

  NNODES = 2
  NINT   = 2
  NBR    = 1
  NF     = 1
  NVAR   = 5
  NHREF  = 2

 FLUIDS: N2

 BOUNDARY NODES
 NODE      P         T        RHO           AREA
           (PSI)     (F)      (LBM/FT^3)    (IN^2)
         ISTEP = 1        TAU = 0.10000E-03
 BOUNDARY NODES
 NODE      P(PSI)    TF(F)     Z(COMP)     RHO       QUALITY       (LBM/FT^3)
```

```
SOLUTION
INTERNAL NODES
 NODE    P(PSI)        TF(F)         Z             RHO           EM(LBM)       QUALITY
                                                   (LBM/FT^3)
  1      0.1471E+02    0.7510E+02    0.1000E+01    0.7182E-01    0.1028E-02    0.1000E+01
  2      0.1471E+02    0.7510E+02    0.1000E+01    0.7182E-01    0.1028E-02    0.1000E+01

 NODE   H             ENTROPY        EMU           COND          CP             GAMA
        BTU/LB        BTU/LB-R       LBM/FT-SEC    BTU/FT-S-R    BTU/LB-R

  1     0.1975E+03    0.1054E+01     0.1199E-04    0.4154E-05    0.2487E+00     0.1401E+01
  2     0.1975E+03    0.1054E+01     0.1199E-04    0.4154E-05    0.2487E+00     0.1401E+01

BRANCHES
 BRANCH   KFACTOR      DELP        FLOW RATE   VELOCITY   REYN. NO.  MACH NO.     ENTROPY GEN. LOST WORK
          (LBF-S^2/    (PSI)       (LBM/SEC)   (FT/SEC)              BTU/(R-SEC)  LBF-FT/SEC
          (LBM-FT)^2)
  12      0.000E+00   0.000E+00   0.000E+00   0.000E+00  0.000E+00  0.000E+00    0.000E+00    0.000E+00

         ***** TOTAL ENTROPY GENERATION =     0.000E+00 BTU/(R-SEC) ******

         **** TOTAL WORK LOST =       0.000E+00 HP *****

                :
                :
                :
                :

        ISTEP = 250     TAU = 0.25000E-01
BOUNDARY NODES
        NODE    P(PSI)  TF(F)   Z(COMP) RHO     QUALITY
                        (LBM/FT^3)

SOLUTION
INTERNAL NODES
 NODE     P(PSI)        TF(F)          Z             RHO             EM(LBM)       QUALITY
                                                     (LBM/FT^3)
  1       0.2235E+03    0.6933E+03     0.1007E+01    0.5024E+00      0.1028E-02    0.1000E+01
  2       0.2235E+03    0.6933E+03     0.1007E+01    0.5024E+00      0.1028E-02    0.1000E+01

 NODE   H             ENTROPY        EMU           COND          CP              GAMA
        BTU/LB        BTU/LB-R       LBM/FT-SEC    BTU/FT-S-R    BTU/LB-R

  1     0.3536E+03    0.1054E+01     0.2052E-04    0.7338E-05    0.2597E+00     0.1382E+01
  2     0.3536E+03    0.1054E+01     0.2052E-04    0.7338E-05    0.2597E+00     0.1382E+01

BRANCHES
BRANCH  KFACTOR      DELP        FLOW RATE   VELOCITY   REYN. NO.  MACH NO.     ENTROPY GEN.   LOST WORK
        (LBF-S^2/    (PSI)       (LBM/SEC)   (FT/SEC)                          BTU/(R-SEC)    LBF-FT/SEC
(       LBM-FT)^2)
  12    0.125E+22    0.000E+00   0.620E-23   0.251E-21  0.154E-17  0.149E-24    0.658E-54      0.590E-48


        ***** TOTAL ENTROPY GENERATION =     0.658E-54 BTU/(R-SEC) ******

        **** TOTAL WORK LOST = 0.107E-50 HP *****


AT ISTEP= 250
WARNING! CHKGASP: T out of fluid property range at node     1

AT ISTEP= 250
WARNING! CHKGASP: T out of fluid property range at node     2
```

```
              :
              :
              :
              :

       ISTEP = 500    TAU = 0.50000E-01
BOUNDARY NODES
       NODE           P(PSI)         TF(F)          Z(COMP)        RHO            QUALITY
                                                                    (LBM/FT^3)

SOLUTION
INTERNAL NODES
 NODE   P(PSI)         TF(F)          Z              RHO            EM(LBM)        QUALITY
                                                     (LBM/FT^3)
  1     0.1470E+02     0.7501E+02     0.1000E+01     0.7179E-01     0.1028E-02     0.1000E+01
  2     0.1470E+02     0.7501E+02     0.1000E+01     0.7179E-01     0.1028E-02     0.1000E+01

 NODE   H              ENTROPY        EMU            COND           CP             GAMA
        BTU/LB         BTU/LB-R       LBM/FT-SEC     BTU/FT-S-R     BTU/LB-R

  1     0.1975E+03     0.1054E+01     0.1199E-04     0.4153E-05     0.2487E+00     0.1401E+01
  2     0.1975E+03     0.1054E+01     0.1199E-04     0.4153E-05     0.2487E+00     0.1401E+01

       BRANCHES
BRANCH KFACTOR      DELP       FLOW RATE  VELOCITY   REYN. NO.   MACH NO.    ENTROPY GEN.  LOST WORK
       (LBF-S^2/    (PSI)      (LBM/SEC)  (FT/SEC)               BTU/(R-SEC) LBF-FT/SEC
       (LBM-FT)^2)
 12    0.510E+22    0.000E+00  0.620E-23  0.176E-20  0.263E-17   0.152E-23   0.406E-52     0.169E-46


        ***** TOTAL ENTROPY GENERATION =     0.406E-52 BTU/(R-SEC) ******

        **** TOTAL WORK LOST =       0.307E-49 HP *****
```

```
 TIME OF ANALYSIS WAS  1.09156960000000      SECS
```

APPENDIX M—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 10

Power Balancing of a Turbopump Assembly

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
PS
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex10\Ex10.dat
OUTPUT FILE NAME
Ex10.out
TITLE
Power Balancing of a Turbopump Assembly
USETUP
F
DENCON      GRAVITY     ENERGY      MIXTURE     THRUST      STEADY      TRANSV      SAVER
F           F           T           F           F           T           F           F
HEX         HCOEF       REACTING    INERTIA     CONDX       ADDPROP     PRINTI      ROTATION
T           T           F           F           F           F           F           F
BUOYANCY    HRATE       INVAL       MSORCE      MOVBND      TPA         VARGEO      TVM
F           T           F           F           F           T           F           F
SHEAR       PRNTIN      PRNTADD     OPVALVE     TRANSQ      CONJUG      RADIAT      WINPLOT
F           F           T           F           F           F           F           T
PRESS       INSUC       VARROT      CYCLIC      CHKVALS     WINFILE     DALTON
F           F           F           F           F           T           F
NORMAL      SIMUL       SECONDL     NRSOLVT
F           T           F           F
NNODES      NINT        NBR         NF
 20         17          20          1
RELAXK      RELAXD      RELAXH      CC          NITER
 1          0.5         1           0.0001      500
NFLUID(I), I = 1, NF
 10
NODE     INDEX     DESCRIPTION
 1       2         "Node 1"
 2       1         "Node 2"
 3       1         "Node 3"
 4       1         "Node 4"
 5       1         "Node 5"
 6       1         "Node 6"
 7       1         "Node 7"
 8       1         "Node 8"
 9       1         "Node 9"
 10      1         "Node 10"
 11      1         "Node 11"
 12      1         "Node 12"
 13      1         "Node 13"
 14      1         "Node 14"
 15      1         "Node 15"
 16      1         "Node 16"
 17      2         "Node 17"
 18      1         "Node 18"
 19      1         "Node 19"
 20      2         "Node 20"
NODE     PRES (PSI)     TEMP(DEGF)    MASS SOURC    HEAT SOURC    THRST AREA    CONCENTRATION
 1       60             -419          0             0             0
 2       25             -419          0             0             0
 3       25             -419          0             0             0
 4       25             -419          0             0             0
 5       25             -419          0             0             0
 6       25             -419          0             0             0
 7       25             -419          0             0             0
 8       25             -419          0             0             0
 9       25             -419          0             0             0
 10      25             -419          0             0             0
 11      25             -419          0             0             0
 12      25             -419          0             0             0
 13      25             -419          0             0             0
 14      25             -419          0             0             0
 15      25             -419          0             0             0
 16      25             -419          0             0             0
 17      14.7             80          0             0             0
```

```
 18      25             -419          0             200           0
 19      25             -419          0             0             0
 20      14.7             80          0             0             0
INODE       NUMBR       NAMEBR
 2          2           12          23
 3          2           23          34
 4          3           34          45          46
 5          2           45          57
 6          2           46          68
 7          2           57          78
 8          3           78          68          89
 9          2           89          910
 10         2           910         1011
 11         2           1011        1112
 12         2           1112        1213
 13         2           1213        1314
 14         2           1314        1415
 15         2           1415        1516
 16         3           1516        1617        1618
 18         2           1618        1819
 19         2           1819        1920
BRANCH      UPNODE      DNNODE      OPTION      DESCRIPTION
12          1           2           16          "CV 12"
23          2           3           15          "Pump 23"
34          3           4           1           "Pipe 34"
45          4           5           1           "Pipe 45"
57          5           7           1           "Pipe 57"
78          7           8           1           "Pipe 78"
46          4           6           1           "Pipe 46"
68          6           8           1           "Pipe 68"
89          8           9           16          "CV 89"
910         9           10          1           "Pipe 910"
1011        10          11          1           "Pipe 1011"
1112        11          12          16          "CV 1112"
1213        12          13          15          "Pump 1213"
1314        13          14          1           "Pipe 1314"
1415        14          15          1           "Pipe 1415"
1516        15          16          1           "Pipe 1516"
1617        16          17          16          "CV 1617"
1618        16          18          16          "CV 1618"
1819        18          19          1           "Pipe 1819"
1920        19          20          1           "Pipe 1920"
BRANCH   OPTION -16      CV             AREA
 12                      2.877          0.19635
BRANCH   OPTION -15      HORSEPOWER     EFFICIENCY    AREA
 23                      0              0.8           0.12112
BRANCH   OPTION -1     LENGTH       DIA         EPSD        ANGLE       AREA
 34                    100          0.3927      0.0025      0           0.12112
BRANCH   OPTION -1     LENGTH       DIA         EPSD        ANGLE       AREA
 45                    100          0.3927      0.0025      0           0.12112
BRANCH   OPTION -1     LENGTH       DIA         EPSD        ANGLE       AREA
 57                    100          0.3927      0.0025      0           0.12112
BRANCH   OPTION -1     LENGTH       DIA         EPSD        ANGLE       AREA
 78                    100          0.3927      0.0025      0           0.12112
BRANCH   OPTION -1     LENGTH       DIA         EPSD        ANGLE       AREA
 46                    100          0.3927      0.0025      0           0.12112
BRANCH   OPTION -1     LENGTH       DIA         EPSD        ANGLE       AREA
 68                    100          0.3927      0.0025      0           0.12112
BRANCH   OPTION -16    CV           AREA
 89                    3.554        0.19635
BRANCH   OPTION -1     LENGTH       DIA         EPSD        ANGLE       AREA
 910                   100          0.3927      0.0025      0           0.12112
BRANCH   OPTION -1     LENGTH       DIA         EPSD        ANGLE       AREA
 1011                  100          0.3927      0.0025      0           0.12112
BRANCH   OPTION -16    CV           AREA
 1112                  3.554        0.19635
BRANCH   OPTION -15    HORSEPOWER   EFFICIENCY  AREA
 1213                  0            1           0.019635
BRANCH   OPTION -1     LENGTH       DIA         EPSD        ANGLE       AREA
 1314                  100          0.3927      0.0025      0           0.12112
```

```
BRANCH   OPTION -1     LENGTH       DIA         EPSD       ANGLE      AREA
 1415                  100          0.3927      0.0025     0          0.12112
BRANCH   OPTION -1     LENGTH       DIA         EPSD       ANGLE      AREA
 1516                  100          0.3927      0.0025     0          0.12112
BRANCH   OPTION -16    CV           AREA
 1617                  0.00354      0.01
BRANCH   OPTION -16    CV           AREA
 1618                  3.554        0.19635
BRANCH   OPTION -1     LENGTH       DIA         EPSD       ANGLE      AREA
 1819                  100          0.3927      0.0025     0          0.12112
BRANCH   OPTION -1     LENGTH       DIA         EPSD       ANGLE      AREA
 1920                  100          0.3927      0.0025     0          0.12112
NUMBER OF HEAT EXCHANGERS
2
IBRHOT    IBRCLD      ITYPHX     ARHOT     ARCOLD      UA       HEXEFF
1415      57          2          0         0           0        0.8
1819      910         2          0         0           0        0.9
NUMBER OF TURBOPUMP ASSEMBLY IN THE CIRCUIT
1
IBRPMP    IBRTRB      SPEED(RPM)     EFFTURB       DIATRB       PSITRD
23        1213        80000          0.5           3.435        0.4
PUMP CHARACTERISTICS CURVE DATA FILE
ex11pmp23.dat
```

Example 10 Pump Characteristic Data File
EX11PMP23.DAT

```
18
0.000          8.680E-06      0.000
3.035E-05      8.971E-06      8.8724E-10
6.071E-05      9.190E-06      9.7065E-10
9.106E-05      9.341E-06      1.0804E-09
1.214E-04      9.436E-06      1.2166E-09
1.518E-04      9.486E-06      1.3393E-09
1.821E-04      9.486E-06      1.4570E-09
2.125E-04      9.445E-06      1.5644E-09
2.428E-04      9.372E-06      1.6733E-09
2.732E-04      9.263E-06      1.7872E-09
3.035E-04      9.117E-06      1.9105E-09
3.339E-04      8.935E-06      2.0558E-09
3.643E-04      8.753E-06      2.2161E-09
3.718E-04      8.689E-06      2.2698E-09
3.749E-04      8.625E-06      2.2869E-09
3.794E-04      8.479E-06      2.3215E-09
3.807E-04      8.388E-06      2.3281E-09
3.810E-04      0.000E+00      0.000
```

```
        G F S S P (Version 5.0)
       Generalized Fluid System Simulation Program
                    September, 2006
     Developed by NASA/Marshall Space Flight Center
       Copyright © by Marshall Space Flight Center

    A generalized computer program to calculate flow
    rates, pressures, temperatures and concentrations
    in a flow network.
```

```
 TITLE    :Power Balancing of a Turbopump Assembly
 ANALYST  :PS\
 FILEIN   :C:\Program Files\GFSSP\Examples\Ex11\Ex11.dat\
 FILEOUT  :Ex11.out\
 LOGICAL VARIABLES
  DENCON   = F
  GRAVITY  = F
  ENERGY   = T
  MIXTURE  = F
  THRUST   = F
  STEADY   = T
  TRANSV   = F
  SAVER    = F
  HEX      = T
  HCOEF    = T
  REACTING = F
  INERTIA  = F
  CONDX    = F
  TWOD     = F
  PRINTI   = F
  ROTATION = F
  BUOYANCY = F
  HRATE    = T
  INVAL    = F
  MSORCE   = F
  MOVBND   = F
  TPA      = T
  VARGEO   = F
  TVM      = F
  SHEAR    = F
  PRNTIN   = F
  PRNTADD  = T
  ADDPROP  = F
  PRESS    = F
  INSUC    = F
  VARROT   = F
  NORMAL   = F
  SECONDL  = F
  CONJUG   = F
  NRSOLVT  = F

  NNODES   = 20
  NINT     = 17
  NBR      = 20
  NF       =  1
  NVAR     = 37
  NHREF    =  2

 FLUIDS: H2

 BOUNDARY NODES
 NODE      P              T              RHO            AREA
           (PSI)          (F)            (LBM/FT^3)     (IN^2)
  1        0.6000E+02     -0.4190E+03    0.4267E+01     0.0000E+00
  17       0.1470E+02     0.8000E+02     0.5112E-02     0.0000E+00
  20       0.1470E+02     0.8000E+02     0.5112E-02     0.0000E+00
```

1

IBRPMP	IBRTRB	SPEED(RPM)	ETATRB	PSITR	TORQUE(LB-IN)	HPOWER
23	1213	0.800E+05	0.000E+00	0.000E+00	0.000E+00	0.000E+00

SOLUTION

INTERNAL NODES

NODE	P(PSI)	TF(F)	Z	RHO (LBM/FT^3)	EM(LBM)	QUALITY
2	0.5542E+02	-0.4190E+03	0.6012E-01	0.4262E+01	0.0000E+00	0.0000E+00
3	0.1790E+04	-0.4074E+03	0.1370E+01	0.4700E+01	0.0000E+00	0.0000E+00
4	0.1780E+04	-0.4072E+03	0.1361E+01	0.4693E+01	0.0000E+00	0.0000E+00
5	0.1778E+04	-0.4072E+03	0.1360E+01	0.4692E+01	0.0000E+00	0.0000E+00
6	0.1775E+04	-0.4072E+03	0.1357E+01	0.4690E+01	0.0000E+00	0.0000E+00
7	0.1777E+04	-0.1462E+03	0.1091E+01	0.9764E+00	0.0000E+00	0.1000E+01
8	0.1771E+04	-0.3066E+03	0.1063E+01	0.2046E+01	0.0000E+00	0.1000E+01
9	0.1765E+04	-0.3066E+03	0.1062E+01	0.2040E+01	0.0000E+00	0.1000E+01
10	0.1741E+04	0.1474E+03	0.1065E+01	0.5061E+00	0.0000E+00	0.1000E+01
11	0.1645E+04	0.1478E+03	0.1061E+01	0.4794E+00	0.0000E+00	0.1000E+01
12	0.1618E+04	0.1479E+03	0.1060E+01	0.4719E+00	0.0000E+00	0.1000E+01
13	0.1078E+04	0.9029E+02	0.1043E+01	0.3531E+00	0.0000E+00	0.1000E+01
14	0.9403E+03	0.9075E+02	0.1038E+01	0.3093E+00	0.0000E+00	0.1000E+01
15	0.7830E+03	-0.3869E+01	0.1034E+01	0.3120E+00	0.0000E+00	0.1000E+01
16	0.6272E+03	-0.3550E+01	0.1028E+01	0.2514E+00	0.0000E+00	0.1000E+01
18	0.5766E+03	0.2489E+03	0.1020E+01	0.1498E+00	0.0000E+00	0.1000E+01
19	0.2539E+03	-0.2250E+03	0.1008E+01	0.2016E+00	0.0000E+00	0.1000E+01

NODE	H BTU/LB	ENTROPY BTU/LB-R	EMU LBM/FT-SEC	COND BTU/FT-S-R	CP BTU/LB-R	GAMA
2	-0.9824E+02	0.6868E+01	0.7636E-05	0.1636E-04	0.2562E+01	0.1935E+01
3	-0.2292E+02	0.6868E+01	0.9984E-05	0.2255E-04	0.2462E+01	0.1536E+01
4	-0.2292E+02	0.6868E+01	0.9926E-05	0.2252E-04	0.2469E+01	0.1539E+01
5	-0.2292E+02	0.6868E+01	0.9919E-05	0.2251E-04	0.2469E+01	0.1540E+01
6	-0.2292E+02	0.6868E+01	0.9901E-05	0.2251E-04	0.2472E+01	0.1541E+01
7	0.9610E+03	0.6868E+01	0.4449E-05	0.2579E-04	0.4051E+01	0.1394E+01
8	0.3228E+03	0.6868E+01	0.3649E-05	0.1629E-04	0.3731E+01	0.1813E+01
9	0.3228E+03	0.6868E+01	0.3644E-05	0.1627E-04	0.3730E+01	0.1813E+01
10	0.2065E+04	0.6868E+01	0.6567E-05	0.3408E-04	0.3539E+01	0.1411E+01
11	0.2065E+04	0.6868E+01	0.6560E-05	0.3405E-04	0.3536E+01	0.1410E+01
12	0.2065E+04	0.6868E+01	0.6558E-05	0.3405E-04	0.3536E+01	0.1410E+01
13	0.1854E+04	0.6868E+01	0.6093E-05	0.3192E-04	0.3576E+01	0.1401E+01
14	0.1854E+04	0.6868E+01	0.6081E-05	0.3189E-04	0.3571E+01	0.1399E+01
15	0.1508E+04	0.6868E+01	0.5358E-05	0.2852E-04	0.3715E+01	0.1382E+01
16	0.1508E+04	0.6868E+01	0.5339E-05	0.2848E-04	0.3706E+01	0.1379E+01
18	0.2404E+04	0.6868E+01	0.7151E-05	0.3681E-04	0.3497E+01	0.1400E+01
19	0.6558E+03	0.6868E+01	0.3402E-05	0.1808E-04	0.3794E+01	0.1381E+01

BRANCHES

BRANCH	KFACTOR (LBF-S^2/ (LBM-FT)^2)	DELP (PSI)	FLOW RATE (LBM/SEC)	VELOCITY (FT/SEC)	REYN. NO.	MACH NO.	ENTROPY GEN. BTU/(R-SEC)	LOST WORK LBF-FT/SEC
12	0.132E+05	0.458E+01	0.224E+00	0.385E+02	0.892E+06	0.277E-01	0.110E-02	0.346E+02
23	0.000E+00	-0.173E+04	0.224E+00	0.625E+02	0.114E+07	0.448E-01	0.000E+00	0.000E+00
34	0.298E+05	0.104E+02	0.224E+00	0.566E+02	0.872E+06	0.403E-01	0.175E-02	0.712E+02
45	0.302E+05	0.130E+01	0.787E-01	0.199E+02	0.308E+06	0.141E-01	0.770E-04	0.314E+01
57	0.303E+05	0.130E+01	0.787E-01	0.199E+02	0.309E+06	0.141E-01	0.770E-04	0.314E+01
78	0.144E+06	0.618E+01	0.787E-01	0.958E+02	0.688E+06	0.292E-01	0.294E-03	0.717E+02
46	0.300E+05	0.439E+01	0.145E+00	0.368E+02	0.569E+06	0.261E-01	0.480E-03	0.196E+02
68	0.300E+05	0.439E+01	0.145E+00	0.368E+02	0.571E+06	0.261E-01	0.480E-03	0.196E+02
89	0.180E+05	0.626E+01	0.224E+00	0.803E+02	0.187E+07	0.307E-01	0.829E-03	0.987E+02
910	0.684E+05	0.238E+02	0.224E+00	0.130E+03	0.239E+07	0.499E-01	0.316E-02	0.376E+03
1011	0.276E+06	0.962E+02	0.224E+00	0.526E+03	0.133E+07	0.114E+00	0.130E-01	0.613E+04
1112	0.768E+05	0.267E+02	0.224E+00	0.343E+03	0.104E+07	0.745E-01	0.380E-02	0.180E+04
1213	0.000E+00	0.540E+03	0.224E+00	0.348E+04	0.330E+07	0.757E+00	0.000E+00	0.000E+00
1314	0.396E+06	0.138E+03	0.224E+00	0.754E+03	0.143E+07	0.173E+00	0.294E-01	0.126E+05
1415	0.452E+06	0.157E+03	0.224E+00	0.861E+03	0.143E+07	0.197E+00	0.383E-01	0.164E+05
1516	0.448E+06	0.156E+03	0.224E+00	0.853E+03	0.163E+07	0.216E+00	0.454E-01	0.161E+05
1617	0.148E+12	0.613E+03	0.773E-03	0.443E+02	0.196E+05	0.112E-01	0.764E-03	0.271E+03
1618	0.146E+06	0.506E+02	0.223E+00	0.651E+03	0.128E+07	0.165E+00	0.182E-01	0.647E+04
1819	0.933E+06	0.323E+03	0.223E+00	0.177E+04	0.121E+07	0.358E+00	0.125E+00	0.692E+05
1920	0.692E+06	0.239E+03	0.223E+00	0.132E+04	0.255E+07	0.466E+00	0.209E+00	0.381E+05

1

IBRPMP	IBRTRB	SPEED(RPM)	ETATRB	PSITR	TORQUE(LB-IN)	HPOWER
23	1213	0.800E+05	0.578E+00	0.269E+00	0.511E+02	0.649E+02

TIME OF ANALYSIS WAS 0.510734400000000 SECS

APPENDIX N—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 11

Steady State & Transient Conduction Through a Circular Rod, with Convection

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
Alok Majumdar
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex11\Ex11.dat
OUTPUT FILE NAME
Ex11.out
TITLE
Steady State & Transient Conduction Through a Circular Rod, With Convection
USETUP
F
DENCON      GRAVITY     ENERGY      MIXTURE     THRUST      STEADY      TRANSV      SAVER
F           F           T           F           F           T           F           F
HEX         HCOEF        REACTING   INERTIA     CONDX       ADDPROP     PRINTI      ROTATION
F           F           F           F           F           F           T           F
BUOYANCY    HRATE       INVAL        MSORCE     MOVBND      TPA         VARGEO      TVM
F           T           F           F           F           F           F           F
SHEAR       PRNTIN      PRNTADD     OPVALVE     TRANSQ      CONJUG      RADIAT      WINPLOT
F           T           T           F           F           T           F           T
PRESS       INSUC       VARROT      CYCLIC      CHKVALS     WINFILE     DALTON
F           F           F           F           F           F           F
NORMAL      SIMUL       SECONDL     NRSOLVT
F           T           F           F
NNODES      NINT        NBR         NF
 4          2           3           1
RELAXK      RELAXD      RELAXH      CC          NITER
 1          0.5         1           0.0001      500
NFLUID(I), I = 1, NF
 11
NODE    INDEX   DESCRIPTION
 11     2       "Node 11"
 12     1       "Node 12"
 13     1       "Node 13"
 14     2       "Node 14"
 NODE   PRES (PSI)    TEMP(DEGF)    MASS SOURC     HEAT SOURC    THRST AREA    CONCENTRATION
 11     50            70            0              0             0
 12     14.7          60            0              0             0
 13     14.7          60            0              0             0
 14     45            70            0              0             0
INODE       NUMBR      NAMEBR
 12         2          1112     1213
 13         2          1213     1314
BRANCH      UPNODE     DNNODE      OPTION     DESCRIPTION
 1112       11         12          1          "Pipe 1112"
 1213       12         13          1          "Pipe 1213"
 1314       13         14          1          "Pipe 1314"

BRANCH     OPTION -1    LENGTH       DIA        EPSD       ANGLE       AREA
 1112                   0.1          1.73       0          0           2.3506
BRANCH     OPTION -1    LENGTH       DIA        EPSD       ANGLE       AREA
 1213                   12           1.73       0          0           2.3506
BRANCH     OPTION -1    LENGTH       DIA        EPSD       ANGLE       AREA
 1314                   12           1.73       0          0           2.3506
NSOLID     NAMB         NSSC         NSFC       NSAC       NSSR
 8          2           7            8          2          0
NODESL MATRL     SMASS         TS           NUMSS     NUMSF     NUMSA       NUMSSR       DESCRIPTION
 2    41         1.00000       70.00000     1         1         1           0            "S Node 2"
NAMESS
 23
NAMESF
 122
NAMESA
 12
 3    41         1.00000       70.00000     2         1         0           0            "S Node 3"
NAMESS
 23   34
```

```
NAMESF
 123
 4    41          1.00000      70.00000     2         1         0          0           "S Node 4"
NAMESS
 34   45
NAMESF
 124
 5    41          1.00000      70.00000     2         1         0          0           "S Node 5"
NAMESS
 45   56
NAMESF
 125
 6    41          1.00000      70.00000     2         1         0          0           "S Node 6"
NAMESS
 56   67
NAMESF
 136
 7    41          1.00000      70.00000     2         1         0          0           "S Node 7"
NAMESS
 67   78
NAMESF
 137
 8    41          1.00000      70.00000     2         1         0          0           "S Node 8"
NAMESS
 78   89
NAMESF
 138
 9    41          1.00000      70.00000     1         1         1          0           "S Node 9"
NAMESS
 89
NAMESF
 139
NAMESA
 910
NODEAM     TAMB          DESCRIPTION
 1         32.00000      "A Node 1"
 10        212.00000     "A Node 10"
ICONSS     ICNSI     ICNSJ      ARCSIJ       DISTSIJ      DESCRIPTION
 23        2         3          3.14159      3.00000      "Conductor 23"
 34        3         4          3.14159      3.00000      "Conductor 34"
 45        4         5          3.14159      3.00000      "Conductor 45"
 56        5         6          3.14159      3.00000      "Conductor 56"
 67        6         7          3.14159      3.00000      "Conductor 67"
 78        7         8          3.14159      3.00000      "Conductor 78"
 89        8         9          3.14159      3.00000      "Conductor 89"
ICONSF    ICS    ICF    MODEL   ARSF           HCSF           EMSFS         EMSFF         DESCRIPTION
 122      2      12     0       1.88500e+01    3.17000e-04    0.00000e+00   0.00000e+00   "Convection 122"
 123      3      12     0       1.88500e+01    3.17000e-04    0.00000e+00   0.00000e+00   "Convection 123"
 124      4      12     0       1.88500e+01    3.17000e-04    0.00000e+00   0.00000e+00   "Convection 124"
 125      5      12     0       1.88500e+01    3.17000e-04    0.00000e+00   0.00000e+00   "Convection 125"
 136      6      13     0       1.88500e+01    3.17000e-04    0.00000e+00   0.00000e+00   "Convection 136"
 137      7      13     0       1.88500e+01    3.17000e-04    0.00000e+00   0.00000e+00   "Convection 137"
 138      8      13     0       1.88500e+01    3.17000e-04    0.00000e+00   0.00000e+00   "Convection 138"
 139      9      13     0       1.88500e+01    3.17000e-04    0.00000e+00   0.00000e+00   "Convection 139"
ICONSA    ICSAS     ICSAA    ARSA           HCSA           EMSAS         EMSAA         DESCRIPTION
 12       2         1        3.14159e+00    2.00000e-02    0.00000e+00   0.00000e+00   "Convection 12"
 910      9         10       3.14159e+00    2.00000e-02    0.00000e+00   0.00000e+00   "Convection 910"
```

EXAMPLE 11 PROPERTY FILES

USER1CP.PRP

```
2
0       0.1981
1000    0.1981
```

USER1K.PRP

```
2
0       0.002611
1000    0.002611
```

```
               G F S S P (Version 5.0)
      Generalized Fluid System Simulation Program
                   September, 2006
     Developed by NASA/Marshall Space Flight Center
      Copyright © by Marshall Space Flight Center

    A generalized computer program to calculate flow
    rates, pressures, temperatures and concentrations
    in a flow network.
```

```
TITLE   :Steady State & Transient Conduction Through a Circular Rod, With Convection
ANALYST :Alok Majumdar
FILEIN  :C:\Program Files\GFSSP\Examples\Ex11\Ex11.dat
FILEOUT :Ex11.out

LOGICAL VARIABLES
 DENCON   = F
 GRAVITY  = F
 ENERGY   = T
 MIXTURE  = F
 THRUST   = F
 STEADY   = T
 TRANSV   = F
 SAVER    = F
 HEX      = F
 HCOEF    = F
 REACTING = F
 INERTIA  = F
 CONDX    = F
 TWOD     = F
 PRINTI   = T
 ROTATION = F
 BUOYANCY = F
 HRATE    = T
 INVAL    = F
 MSORCE   = F
 MOVBND   = F
 TPA      = F
 VARGEO   = F
 TVM      = F
 SHEAR    = F
 PRNTIN   = T
 PRNTADD  = T
 ADDPROP  = F
 PRESS    = F
 INSUC    = F
 VARROT   = F
 NORMAL   = F
 SECONDL  = F
 CONJUG   = T
 NRSOLVT  = F

 NNODES   = 4
 NINT     = 2
 NBR      = 3
 NF       = 1
 NVAR     = 5
 NHREF    = 2

FLUIDS: H2O
```

```
BOUNDARY NODES
 NODE       P               T             RHO            AREA
            (PSI)           (F)           (LBM/FT^3)     (IN^2)
 11         0.5000E+02      0.7000E+02    0.6231E+02     0.0000E+00
 14         0.4500E+02      0.7000E+02    0.6231E+02     0.0000E+00

INPUT SPECIFICATIONS FOR INTERNAL NODES
NODE       AREA            MASS            HEAT
           (IN^2)          (LBM/S)         (BTU/S)
 12        0.0000E+00      0.0000E+00      0.0000E+00
 13        0.0000E+00      0.0000E+00      0.0000E+00

BRANCH     UPNODE      DNNODE     OPTION
 1112      11          12         1
 1213      12          13         1
 1314      13          14         1
BRANCH OPTION -1:      LENGTH, DIA, EPSD, ANGLE, AREA
 1112      0.100E+00   0.173E+01    0.000E+00     0.000E+00    0.235E+01
BRANCH OPTION -1:      LENGTH, DIA, EPSD, ANGLE, AREA
 1213      0.120E+02   0.173E+01    0.000E+00     0.000E+00    0.235E+01
BRANCH OPTION -1:      LENGTH, DIA, EPSD, ANGLE, AREA
 1314      0.120E+02   0.173E+01    0.000E+00     0.000E+00    0.235E+01

INITIAL GUESS FOR INTERNAL NODES
 NODE     P(PSI)         TF(F)          Z(COMP)         RHO            QUALITY
                                                        (LBM/FT^3)
 12       0.1470E+02     0.6000E+02     0.7616E-03      0.6237E+02     0.0000E+00
 13       0.1470E+02     0.6000E+02     0.7616E-03      0.6237E+02     0.0000E+00

TRIAL SOLUTION
        BRANCH  DELP(PSI)       FLOWRATE(LBM/SEC)
 1112    0.0000 0.0100
 1213    0.0000 0.0100
 1314    0.0000 0.0100


CONJUGATE HEAT TRANSFER
 NSOLIDX= 8
 NAMB   = 2
 NSSC   = 7
 NSFC   = 8
 NSAC   = 2
 NSSR   = 0
NODESL         MATRL     SMASS     TS          NUMSS       NUMSF      NUMSA
      2        41        1.0000    70.0000     1           1          1
 NAMESS
     23
 NAMESF
    122
 NAMESA
     12
NODESL         MATRL     SMASS     TS          NUMSS       NUMSF      NUMSA
      3        41        1.0000    70.0000     2           1          0
 NAMESS
     23        34
 NAMESF
    123
NODESL         MATRL     SMASS     TS          NUMSS       NUMSF      NUMSA
      4        41        1.0000    70.0000     2           1          0
 NAMESS
     34        45
 NAMESF
    124
NODESL         MATRL     SMASS     TS          NUMSS       NUMSF      NUMSA
      5        41        1.0000    70.0000     2           1          0
 NAMESS
     45        56
 NAMESF
    125
NODESL         MATRL     SMASS     TS          NUMSS       NUMSF      NUMSA
      6        41        1.0000    70.0000     2           1          0
```

```
 NAMESS
     56        67
 NAMESF
    136
NODESL         MATRL     SMASS     TS          NUMSS       NUMSF      NUMSA
      7        41        1.0000    70.0000     2           1          0
 NAMESS
     67        78
 NAMESF
    137
NODESL         MATRL     SMASS     TS          NUMSS       NUMSF      NUMSA
      8        41        1.0000    70.0000     2           1          0
 NAMESS
     78        89
 NAMESF
    138
NODESL         MATRL     SMASS     TS          NUMSS       NUMSF      NUMSA
      9        41        1.0000    70.0000     1           1          1
 NAMESS
  89
 NAMESF
  139
 NAMESA
  910
NODEAM TAMB
 1      32.0000
 10     212.0000
ICONSS      ICNSI      ICNSJ     ARCSIJ     DISTSIJ
 23         2          3         3.1416     3.0000
 34         3          4         3.1416     3.0000
 45         4          5         3.1416     3.0000
 56         5          6         3.1416     3.0000
 67         6          7         3.1416     3.0000
 78         7          8         3.1416     3.0000
 89         8          9         3.1416     3.0000
ICONSF      ICS        ICF       ARSF       EMSFS
 122        2          12        18.8500    0.0000      0.0000
 123        3          12        18.8500    0.0000      0.0000
 124        4          12        18.8500    0.0000      0.0000
 125        5          12        18.8500    0.0000      0.0000
 136        6          13        18.8500    0.0000      0.0000
 137        7          13        18.8500    0.0000      0.0000
 138        8          13        18.8500    0.0000      0.0000
 139        9          13        18.8500    0.0000      0.0000
ICONSA      ICSAS      ICSAA     ARSA            HCSA           EMSAS          EMSAA
 12         2          1         0.3142E+01      0.2000E-01     0.0000E+00     0.0000E+00
 910        9          10        0.3142E+01      0.2000E-01     0.0000E+00     0.0000E+00

SOLUTION
INTERNAL NODES
NODE    P(PSI)         TF(F)          Z              RHO            EM(LBM)        QUALITY
                                      (LBM/FT^3)
 12     0.4998E+02     0.7000E+02     0.2543E-02     0.6231E+02     0.0000E+00     0.0000E+00
 13     0.4749E+02     0.7001E+02     0.2416E-02     0.6231E+02     0.0000E+00     0.0000E+00

NODE    H              ENTROPY        EMU            COND           CP             GAMA
        BTU/LB         BTU/LB-R       LBM/FT-SEC     BTU/FT-S-R     BTU/LB-R

 12     0.3816E+02     0.5542E-01     0.6564E-03     0.9662E-04     0.9998E+00     0.1007E+01
 13     0.3816E+02     0.5542E-01     0.6563E-03     0.9662E-04     0.9998E+00     0.1007E+01
```

BRANCHES

BRANCH	KFACTOR (LBF-S^2/ (LBM-FT)^2)	DELP (PSI)	FLOW RATE (LBM/SEC)	VELOCITY (FT/SEC)	REYN. NO.	MACH NO.	ENTROPY GEN. BTU/(R-SEC)	LOST WORK LBF-FT/SEC
1112	0.639E-03	0.207E-01	0.684E+02	0.672E+02	0.920E+06	0.554E-01	0.795E-05	0.328E+01
1213	0.767E-01	0.249E+01	0.684E+02	0.672E+02	0.920E+06	0.554E-01	0.954E-03	0.393E+03
1314	0.767E-01	0.249E+01	0.684E+02	0.673E+02	0.920E+06	0.555E-01	0.954E-03	0.393E+03

SOLID NODES

NODESL	CPSLD BTU/LB F	TS F
2	0.000E+00	0.423E+02
3	0.000E+00	0.569E+02
4	0.000E+00	0.691E+02
5	0.000E+00	0.812E+02
6	0.000E+00	0.954E+02
7	0.000E+00	0.114E+03
8	0.000E+00	0.141E+03
9	0.000E+00	0.181E+03

SOLID TO SOLID CONDUCTOR

ICONSS	CONDKIJ BTU/S FT F	QDOTSS BTU/S
23	0.261E-02	-0.333E-02
34	0.261E-02	-0.279E-02
45	0.261E-02	-0.276E-02
56	0.261E-02	-0.322E-02
67	0.261E-02	-0.428E-02
78	0.261E-02	-0.611E-02
89	0.261E-02	-0.906E-02

SOLID TO FLUID CONDUCTOR

ICONSF	QDOTSF BTU/S	HCSF BTU/SFT**2 F	HCSFR
122	-0.115E-02	0.317E-03	0.000E+00
123	-0.544E-03	0.317E-03	0.000E+00
124	-0.356E-04	0.317E-03	0.000E+00
125	0.466E-03	0.317E-03	0.000E+00
136	0.105E-02	0.317E-03	0.000E+00
137	0.183E-02	0.317E-03	0.000E+00
138	0.294E-02	0.317E-03	0.000E+00
139	0.459E-02	0.317E-03	0.000E+00

SOLID TO AMBIENT CONDUCTOR

ICONSA	QDOTSA BTU/S	HCSA BTU/S FT**2 F	HCSAR BTU/S FT**2 F
12	0.448E-02	0.200E-01	0.000E+00
910	-0.136E-01	0.200E-01	0.000E+00

SOLUTION SATISFIED CONVERGENCE CRITERION OF 0.100E-03 IN 10 ITERATIONS
TAU = 100000000.000000 ISTEP = 1

TIME OF ANALYSIS WAS 0.130187200000000 SECS

APPENDIX O—INPUT AND OUTPUT DATA FILES FROM EXAMPLE 12

Simulation of Fluid Transient Following Sudden Valve Closure

Contents Page

```
GFSSP VERSION
   503
GFSSP INSTALLATION PATH
C:\Program Files\GFSSP\
ANALYST
Alok Majumdar
INPUT DATA FILE NAME
C:\Program Files\GFSSP\Examples\Ex15\Ex15.dat
OUTPUT FILE NAME
Ex15.out
TITLE
Simulation of Fluid Transient Following Sudden Valve Closure
USETUP
F
DENCON      GRAVITY   ENERGY      MIXTURE    THRUST    STEADY       TRANSV      SAVER
F           F         T           F          F         F            T           F
HEX         HCOEF     REACTING    INERTIA    CONDX     ADDPROP      PRINTI      ROTATION
F           F         F           F          F         F            T           F
BUOYANCY    HRATE     INVAL       MSORCE     MOVBND    TPA          VARGEO      TVM
F           T         T           F          F         F            F           F
SHEAR       PRNTIN    PRNTADD     OPVALVE    TRANSQ    CONJUG       RADIAT      WINPLOT
F           T         T           T          F         F            F           T
PRESS       INSUC     VARROT      CYCLIC     CHKVALS   WINFILE      DALTON
F           F         F           F          F         T            F
NORMAL      SIMUL     SECONDL     NRSOLVT
F           T         F           F
NNODES      NINT      NBR         NF
 7          5         6           1
RELAXK      RELAXD    RELAXH      CC         NITER
 1          0.5       1           0.0001     500
DTAU        TIMEF     TIMEL       NPSTEP     NPWSTEP
 0.02        0        1           1          1
NFLUID(I), I = 1, NF
 6
NODE       INDEX     DESCRIPTION
 1         2         "Node 1"
 2         1         "Node 2"
 3         1         "Node 3"
 4         1         "Node 4"
 5         1         "Node 5"
 6         1         "Node 6"
 7         2         "Node 7"
NODE    PRES (PSI)   TEMP(DEGF)   MASS SOURC   HEAT SOURC   THRST AREA    NODE-VOLUME    CONCENTRATION
 2      14.7         60           0            0            0             0
 3      14.7         60           0            0            0             0
 4      14.7         60           0            0            0             0
 5      14.7         60           0            0            0             0
 6      14.7         60           0            0            0             0
 ex15hs1.dat
 ex15hs7.dat
INODE      NUMBR     NAMEBR
 2         2         12      23
 3         2         23      34
 4         2         34      45
 5         2         45      56
 6         2         56      67
BRANCH     UPNODE    DNNODE    OPTION    DESCRIPTION
12         1         2         1         "Pipe 12"
23         2         3         1         "Pipe 23"
34         3         4         1         "Pipe 34"
45         4         5         1         "Pipe 45"
56         5         6         1         "Pipe 56"
67         6         7         2         "Restrict 67"
BRANCH  OPTION -1    LENGTH    DIA       EPSD       ANGLE      AREA
 12                  960       0.25       0         0          0.049087
BRANCH  OPTION -1    LENGTH    DIA       EPSD       ANGLE      AREA
 23                  960       0.25       0         0          0.049087
BRANCH  OPTION -1    LENGTH    DIA       EPSD       ANGLE      AREA
 34                  960       0.25       0         0          0.049087
BRANCH  OPTION -1    LENGTH    DIA       EPSD       ANGLE      AREA
 45                  960       0.25       0         0          0.049087
```

```
BRANCH  OPTION -1    LENGTH     DIA        EPSD       ANGLE      AREA
 56                  960        0.25       0          0          0.049087
BRANCH  OPTION -2    FLOW COEFF AREA
 67                  0.6        0.0491
INITIAL FLOWRATES IN BRANCHES FOR UNSTEADY FLOW
 12     0
 23     0
 34     0
 45     0
 56     0
 67     0
NUMBER OF CLOSING/OPENING VALVES IN THE CIRCUIT
 1
BRANCH
67
FILE NAME
ex15vlv.dat
RESTART NODE INFORMATION FILE
FNDEX15.DAT
RESTART BRANCH INFORMATION FILE
FBREX15.DAT
```

EXAMPLE 12 HISTORY AND RESTART FILES

```
EX15HS1.DAT
2
0       500.0    -260.0    0.0
1000    500.0    -260.0    0.0


EX15HS7.DAT
2
0       450.0    -260.0    0.0
1000    450.0    -260.0    0.0


EX15VLV.DAT
7
0.00    0.0491
0.02    0.0164
0.04    0.00545
0.06    0.00182
0.08    0.00061
0.1     1.E-16
100     1.E-16

FNDEX15.DAT
NODE        P(PSF)         TF(R)                H(BTU/LB)    CONC RHO(LB/FT^3)
            EMU(LB/FT-S)   Z R(LBF-FT/LB-R)     EM(LB)       CP(BTU/LB-R)       ENTROPY(BTU/LB-R)
  2         70570.99       199.6258             77.07056     1.000000
            64.96349       8.4011677E-05        0.1126991    48.28000         0.0000000E+00    0.4173057
  1.524868
  3          69141.62      199.6527       77.07056      1.000000
  64.94235   8.3891122E-05 0.1104375      48.28000      0.0000000E+00
 0.4175506   1.524851
  4          67712.23      199.6797       77.07058      1.000000
  64.92119   8.3770668E-05 0.1081750      48.28000      0.0000000E+00
 0.4178011   1.524851
  5          66282.80      199.7065       77.07059      1.000000
  64.90001   8.3650339E-05 0.1059117      48.28000      0.0000000E+00
 0.4180055   1.524851
  6          64853.37      199.7332       77.07063      1.000000
  64.87878   8.3530074E-05 0.1036477      48.28000      0.0000000E+00
 0.4182283   1.524851

FBREX15.DAT
BRANCH      AK             FLOWR(LB/S)        VEL(FT/S)
 12         153259.8       9.6560813E-02      4.358272
 23         153280.5       9.6560813E-02      4.360718
 34         153282.9       9.6560813E-02      4.362138
 45         153285.4       9.6560813E-02      4.363560
 56         153287.8       9.6560813E-02      4.364984
 67         5722.974       9.6560813E-02      4.369652
```

```
                G F S S P (Version 5.0)
        Generalized Fluid System Simulation Program
                     September, 2006
       Developed by NASA/Marshall Space Flight Center
        Copyright © by Marshall Space Flight Center

     A generalized computer program to calculate flow
     rates, pressures, temperatures and concentrations
     in a flow network.
```

```
TITLE    :Simulation of Fluid Transient Following Sudden Valve Closure
ANALYST  :Alok Majumdar
FILEIN   :C:\Program Files\GFSSP\Examples\Ex12\Ex12.dat
FILEOUT  :Ex12.out
LOGICAL VARIABLES
 DENCON   = F
 GRAVITY  = F
 ENERGY   = T
 MIXTURE  = F
 THRUST   = F
 STEADY   = F
 TRANSV   = T
 SAVER    = F
 HEX      = F
 HCOEF    = F
 REACTING = F
 INERTIA  = F
 CONDX    = F
 TWOD     = F
 PRINTI   = T
 ROTATION = F
 BUOYANCY = F
 HRATE    = T
 INVAL    = T
 MSORCE   = F
 MOVBND   = F
 TPA      = F
 VARGEO   = F
 TVM      = F
 SHEAR    = F
 PRNTIN   = T
 PRNTADD  = T
 ADDPROP  = F
 PRESS    = F
 INSUC    = F
 VARROT   = F
 NORMAL   = F
 SECONDL  = F
 CONJUG   = F
 NRSOLVT  = F

 NNODES   = 7
 NINT     = 5
 NBR      = 6
 NF       = 1
 NVAR     =16
 NHREF    = 2

FLUIDS: O2

BOUNDARY NODES
NODE    P              T              RHO            AREA
        (PSI)          (F)            (LBM/FT^3)     (IN^2)
 1      0.5000E+03     -0.2600E+03    0.6499E+02     0.0000E+00
 7      0.4500E+03     -0.2600E+03    0.6491E+02     0.0000E+00
```

INPUT SPECIFICATIONS FOR INTERNAL NODES

NODE	AREA (IN^2)	MASS (LBM/S)	HEAT (BTU/S)
2	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00

BRANCH	UPNODE	DNNODE	OPTION
12	1	2	1
23	2	3	1
34	3	4	1
45	4	5	1
56	5	6	1
67	6	7	2

BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
12	0.960E+03	0.250E+00	0.000E+00	0.000E+00	0.491E-01
BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
3	0.960E+03	0.250E+00	0.000E+00	0.000E+00	0.491E-01
BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
34	0.960E+03	0.250E+00	0.000E+00	0.000E+00	0.491E-01
BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
45	0.960E+03	0.250E+00	0.000E+00	0.000E+00	0.491E-01
BRANCH OPTION -1:	LENGTH,	DIA,	EPSD,	ANGLE,	AREA
56	0.960E+03	0.250E+00	0.000E+00	0.000E+00	0.491E-01
BRANCH OPTION -2:	FLOW COEF,	AREA			
67	0.600E+00	0.164E-01			

INITIAL GUESS FOR INTERNAL NODES

NODE	P(PSI)	TF(F)	Z(COMP)	RHO (LBM/FT^3)	QUALITY
2	0.4901E+03	-0.2600E+03	0.1127E+00	0.6496E+02	0.0000E+00
3	0.4802E+03	-0.2599E+03	0.1104E+00	0.6494E+02	0.0000E+00
4	0.4702E+03	-0.2599E+03	0.1082E+00	0.6492E+02	0.0000E+00
5	0.4603E+03	-0.2599E+03	0.1059E+00	0.6490E+02	0.0000E+00
6	0.4504E+03	-0.2599E+03	0.1036E+00	0.6488E+02	0.0000E+00

TRIAL SOLUTION

BRANCH	DELP(PSI)	FLOWRATE(LBM/SEC)
12	0.0000	0.0966
23	0.0000	0.0966
34	0.0000	0.0966
45	0.0000	0.0966
56	0.0000	0.0966
67	0.0000	0.0966

ISTEP = 1 TAU = 0.20000E-01

BOUNDARY NODES

NODE	P(PSI)	TF(F)	Z(COMP)	RHO (LBM/FT^3)	QUALITY
1	0.5000E+03	-0.2600E+03	0.0000E+00	0.6499E+02	0.0000E+00
7	0.4500E+03	-0.2600E+03	0.0000E+00	0.6491E+02	0.0000E+00

SOLUTION

INTERNAL NODES

NODE	P(PSI)	TF(F)	Z	RHO (LBM/FT^3)	EM(LBM)	QUALITY
2	0.4831E+03	-0.2600E+03	0.1111E+00	0.6497E+02	0.2657E+01	0.0000E+00
3	0.4724E+03	-0.2600E+03	0.1087E+00	0.6494E+02	0.1771E+01	0.0000E+00
4	0.4639E+03	-0.2599E+03	0.1067E+00	0.6492E+02	0.1771E+01	0.0000E+00
5	0.4644E+03	-0.2599E+03	0.1068E+00	0.6491E+02	0.1770E+01	0.0000E+00
6	0.4993E+03	-0.2597E+03	0.1147E+00	0.6493E+02	0.8853E+00	0.0000E+00

NODE	H BTU/LB	ENTROPY BTU/LB-R	EMU LBM/FT-SEC	COND BTU/FT-S-R	CP BTU/LB-R	GAMA
2	0.7705E+02	0.1525E+01	0.8398E-04	0.1819E-04	0.4174E+00	0.2026E+01
3	0.7705E+02	0.1525E+01	0.8386E-04	0.1818E-04	0.4177E+00	0.2028E+01
4	0.7705E+02	0.1525E+01	0.8374E-04	0.1817E-04	0.4179E+00	0.2029E+01

```
 5      0.7708E+02    0.1525E+01     0.8367E-04     0.1816E-04    0.4179E+00    0.2030E+01
 6      0.7721E+02    0.1525E+01     0.8376E-04     0.1817E-04    0.4174E+00    0.2028E+01

BRANCHES
BRANCH   KFACTOR      DELP         FLOW RATE   VELOCITY   REYN. NO.   MACH NO.     ENTROPY GEN.  LOST WORK
         (LBF-S^2/    (PSI)        (LBM/SEC)   (FT/SEC)               BTU/(R-SEC)  LBF-FT/SEC
         (LBM-FT)^2)
 12      0.152E+06    0.169E+02    0.999E-01   0.451E+01  0.726E+05   0.569E-02    0.150E-04     0.233E+01
 23      0.153E+06    0.108E+02    0.968E-01   0.437E+01  0.705E+05   0.552E-02    0.138E-04     0.214E+01
 34      0.153E+06    0.847E+01    0.960E-01   0.434E+01  0.700E+05   0.547E-02    0.135E-04     0.209E+01
 45      0.155E+06   -0.464E+00    0.927E-01   0.419E+01  0.677E+05   0.528E-02    0.122E-04     0.190E+01
 56      0.162E+06   -0.350E+02    0.748E-01   0.338E+01  0.547E+05   0.426E-02    0.673E-05     0.105E+01
 67      0.513E+05    0.493E+02    0.409E-01   0.553E+01  0.516E+05   0.697E-02    0.347E-06     0.539E-01

SOLUTION SATISFIED CONVERGENCE CRITERION OF  0.100E-03 IN   283 ITERATIONS
 TAU =  2.000000000000000E-002 ISTEP =        1

                :
                :
                :
                :

       ISTEP = 25      TAU = 0.50000E+00
BOUNDARY NODES
NODE    P(PSI)         TF(F)          Z(COMP)        RHO           QUALITY
                                                     (LBM/FT^3)
 1      0.5000E+03    -0.2600E+03     0.0000E+00     0.6499E+02    0.0000E+00
 7      0.4500E+03    -0.2600E+03     0.0000E+00     0.6491E+02    0.0000E+00

SOLUTION
INTERNAL NODES
NODE    P(PSI)         TF(F)          Z              RHO             EM(LBM)      QUALITY
                                      (              LBM/FT^3)
 2      0.4830E+03    -0.2600E+03     0.1111E+00     0.6497E+02     0.2658E+01    0.0000E+00
 3      0.4549E+03    -0.2601E+03     0.1047E+00     0.6493E+02     0.1771E+01    0.0000E+00
 4      0.4353E+03    -0.2601E+03     0.1003E+00     0.6490E+02     0.1770E+01    0.0000E+00
 5      0.4216E+03    -0.2601E+03     0.9715E-01     0.6488E+02     0.1769E+01    0.0000E+00
 6      0.4180E+03    -0.2600E+03     0.9631E-01     0.6486E+02     0.8844E+00    0.0000E+00

NODE    H              ENTROPY        EMU            COND           CP            GAMA
        BTU/LB         BTU/LB-R       LBM/FT-SEC     BTU/FT-S-R     BTU/LB-R

 2      0.7704E+02     0.1525E+01     0.8400E-04     0.1819E-04     0.4174E+00    0.2026E+01
 3      0.7699E+02     0.1525E+01     0.8379E-04     0.1817E-04     0.4180E+00    0.2029E+01
 4      0.7696E+02     0.1525E+01     0.8363E-04     0.1816E-04     0.4184E+00    0.2031E+01
 5      0.7695E+02     0.1525E+01     0.8349E-04     0.1815E-04     0.4187E+00    0.2032E+01
 6      0.7697E+02     0.1525E+01     0.8340E-04     0.1814E-04     0.4188E+00    0.2033E+01


BRANCHES
BRANCH  KFACTOR      DELP         FLOW RATE   VELOCITY     REYN. NO.   MACH NO.    ENTROPY GEN.  LOST WORK
        (LBF-S^2/    (PSI)        (LBM/SEC)   (FT/SEC)                             BTU/(R-SEC)   LBF-FT/SEC
        (LBM-FT)^2)
 12     0.203E+06    0.170E+02   -0.285E-01  -0.129E+01   0.208E+05   0.163E-02    0.467E-06     0.725E-01
 23     0.215E+06    0.281E+02   -0.225E-01  -0.102E+01   0.164E+05   0.128E-02    0.243E-06     0.377E-01
 34     0.235E+06    0.196E+02   -0.159E-01  -0.717E+00   0.116E+05   0.904E-03    0.931E-07     0.145E-01
 45     0.274E+06    0.137E+02   -0.903E-02  -0.408E+00   0.661E+04   0.514E-03    0.200E-07     0.310E-02
 56     0.237E+06    0.365E+01   -0.292E-02  -0.132E+00   0.214E+04   0.166E-03    0.583E-09     0.906E-04
 67     0.138E+34   -0.320E+02   -0.111E-11  -0.246E+05   0.179E+02   0.309E+02    0.186E-09     0.288E-04


SOLUTION SATISFIED CONVERGENCE CRITERION OF 0.100E-03 IN 101 ITERATIONS
TAU =   0.500000000000000     ISTEP = 25

                :
                :
                :
                :

       ISTEP  =      50            TAU    =      0.10000E+01
```

BOUNDARY NODES

NODE	P(PSI)	TF(F)	Z(COMP)	RHO (LBM/FT^3)	QUALITY
1	0.5000E+03	-0.2600E+03	0.0000E+00	0.6499E+02	0.0000E+00
7	0.4500E+03	-0.2600E+03	0.0000E+00	0.6491E+02	0.0000E+00

SOLUTION

INTERNAL NODES

NODE	P(PSI)	TF(F)	Z	RHO (LBM/FT^3)	EM(LBM)	QUALITY
2	0.5083E+03	-0.2599E+03	0.1168E+00	0.6499E+02	0.2658E+01	0.0000E+00
3	0.5192E+03	-0.2598E+03	0.1193E+00	0.6499E+02	0.1772E+01	0.0000E+00
4	0.5261E+03	-0.2597E+03	0.1208E+00	0.6498E+02	0.1772E+01	0.0000E+00
5	0.5303E+03	-0.2596E+03	0.1217E+00	0.6497E+02	0.1772E+01	0.0000E+00
6	0.5313E+03	-0.2596E+03	0.1220E+00	0.6496E+02	0.8856E+00	0.0000E+00

NODE	H BTU/LB	ENTROPY BTU/LB-R	EMU LBM/FT-SEC	COND BTU/FT-S-R	CP BTU/LB-R	GAMA
2	0.7711E+02	0.1525E+01	0.8413E-04	0.1820E-04	0.4170E+00	0.2024E+01
3	0.7717E+02	0.1525E+01	0.8411E-04	0.1820E-04	0.4168E+00	0.2024E+01
4	0.7722E+02	0.1525E+01	0.8406E-04	0.1819E-04	0.4168E+00	0.2025E+01
5	0.7726E+02	0.1525E+01	0.8401E-04	0.1819E-04	0.4167E+00	0.2025E+01
6	0.7729E+02	0.1525E+01	0.8394E-04	0.1819E-04	0.4168E+00	0.2025E+01

BRANCHES

BRANCH	KFACTOR (LBF-S^2/ (LBM-FT)^2)	DELP (PSI)	FLOW RATE (LBM/SEC)	VELOCITY (FT/SEC)	REYN. NO.	MACH NO.	ENTROPY GEN. BTU/(R-SEC)	LOST WORK LBF-FT/SEC
12	0.189E+06	-0.832E+01	-0.378E-01	-0.171E+01	0.275E+05	0.215E-02	0.101E-05	0.157E+00
23	0.195E+06	-0.109E+02	-0.334E-01	-0.151E+01	0.243E+05	0.190E-02	0.720E-06	0.112E+00
34	0.207E+06	-0.692E+01	-0.263E-01	-0.119E+01	0.191E+05	0.150E-02	0.372E-06	0.578E-01
45	0.232E+06	-0.423E+01	-0.167E-01	-0.755E+00	0.122E+05	0.952E-03	0.107E-06	0.167E-01
56	0.312E+06	-0.104E+01	-0.569E-02	-0.257E+00	0.415E+04	0.324E-03	0.570E-08	0.887E-03
67	0.138E+34	0.814E+02	-0.111E-11	-0.246E+05	0.179E+02	0.310E+02	0.186E-09	0.288E-04

SOLUTION SATISFIED CONVERGENCE CRITERION OF 0.100E-03 IN 128 ITERATIONS
TAU = 1.00000000000000 ISTEP = 50

TIME OF ANALYSIS WAS 27.5996864000000 SECS

APPENDIX P—LIST OF PUBLICATIONS WHERE GFSSP HAS BEEN USED

	Title	Author(s)	Conference/Journal
1	A General Fluid System Simulation Program to Model Secondary Flows in Turbomachinery	Alok Majumdar Katherine Van Hooser	31st AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 10-12, 1995, San Diego, CA, AIAA 95-2969
2	Mathematical Modeling of Free Convective Flows for Evaluating Propellant Conditioning Concepts	Alok Majumdar John Bailey Kimberly Holt Susan Turner	32nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 1-3, 1996, Lake Buena Vista, FL, AIAA 96-3117
3	A Generalized Fluid System Simulation Program to Model Flow Distribution in Fluid Networks	Alok Majumdar John Bailey Biplab Sarkar	33rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 6-9, 1997, Seattle, WA, AIAA 97-3225
4	Numerical Prediction of Pressure Distribution Along the Front and Back Face of a Rotating Disc With and Without Blades	Paul Schallhorn Alok Majumdar	33rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 6-9, 1997, Seattle, WA, AIAA 97-3098
5	Flow Network Analyses of Cryogenic Hydrogen Propellant Storage and Feed Systems	Douglas Richards Daniel Vonderwell	33rd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 6-9, 1997, Seattle, WA, AIAA 97-3223
6	A Generalized Fluid System Simulation Program to Model Flow Distribution in Fluid Networks	Alok Majumdar John Bailey Paul Schallhorn Todd Steadman	34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 13-15, 1998, Cleveland, OH, AIAA 98-3682
7	Flow Simulation in Secondary Flow Passages of a Rocket Engine Turbopump	Paul Schallhorn Alok Majumdar Katherine Van Hooser Matthew Marsh	34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 13-15, 1998, Cleveland, OH, AIAA 98-3684
8	A Novel Approach for Modeling Long Bearing Squeeze Film Damper Performance	Paul Schallhorn David Elrod David Goggin Alok Majumdar	34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 13-15, 1998, Cleveland, OH, AIAA 98-3684
9	Unstructured Finite Volume Computational Thermo-Fluid Dynamics Method for Multi-Disciplinary Analysis and Design Optimization	Alok Majumdar Paul Schallhorn	7th AIAA/USAF/NASA/ISSMO Symposium on Multidisciplinary Analysis and Optimization, September 2-4, 1998, St. Louis, MO AIAA 98-4810
10	Numerical Modeling of Pressurization of a Propellant Tank	Alok Majumdar Todd Steadman	37th AIAA Aerospace Sciences Meeting Conference and Exhibit, January 11-14, 1999, Reno, NV AIAA 99-0879 To be published in AIAA Journal of Propulsion and Power, November-December 2000

	Title	Author(s)	Conference/Journal
11	A Second Law Based Unstructured Finite Volume Procedure for Generalized Flow Simulation	Alok Majumdar	37th AIAA Aerospace Sciences Meeting Conference and Exhibit, January 11-14, 1999, Reno, NV AIAA 99-0934
12	Numerical Prediction of Transient Axial Thrust and Internal Flows in a Rocket Engine Turbopump	Katherine Van Hooser John Bailey Alok Majumdar	35th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, June 21, 1999, Los Angeles, CA, AIAA 99-2189
13	Numerical Modeling of Helium Pressurization System of Propulsion Test Article (PTA)	Todd Steadman Alok Majumdar Kimberly Holt	Thermal & Fluids Analysis Workshop, September 13-17, 1999, Huntsville, AL
14	A Steady State and Quasi-Steady Interface Between the Generalized Fluid System Simulation Program and the SINDA/G Thermal Analysis Program	Paul Schallhorn Alok Majumdar Bruce Tiller	Thermal & Fluids Analysis Workshop, September 13-17, 1999, Huntsville, AL
15	Interfacing a General Purpose Fluid Network Flow Program with the Sinda/G Thermal Analysis Program	Paul Schallhorn Dan Popok	SAE Paper No. 1999-01-2162
16	An Unsteady Long Bearing Squeeze Film Damper Model – Part I: Circular Centered Orbits	Paul Schallhorn David Elrod David Goggin Alok Majumdar	38th AIAA Aerospace Sciences Meeting Conference and Exhibit, January 11-14, 1999, Reno, NV AIAA 2000-0352
17	An Unsteady Long Bearing Squeeze Film Damper Model – Part II: Statically Eccentric Operation	Paul Schallhorn David Elrod David Goggin Alok Majumdar	38th AIAA Aerospace Sciences Meeting Conference and Exhibit, January 11-14, 1999, Reno, NV AIAA 2000-0353
18	A Fluid Circuit Model for Long Bearing Squeeze Film Damper Rotordynamics	Paul Schallhorn David Elrod David Goggin Alok Majumdar	AIAA Journal of Propulsion and Power, Vol. 16, No. 5, pp 777-780, Sept – Oct 2000
19	Unsteady Analysis of the Fluid Film Forces in a Long Bearing Squeeze Film Damper	Paul Schallhorn	Ph. D. Dissertation, University of Alabama in Huntsville, 1998
20	Numerical Modeling and Test Data Comparison of Propulsion Test Article Helium Pressurization System	Kimberly Holt Alok Majumdar Todd Steadman Ali Hedayat	36th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 16-19, 2000, Huntsville, AL, AIAA 2000-3719
21	Numerical Modeling of Drying Residual RP-1 in Rocket Engines	Alok Majumdar Robert Polsgrove Bruce Tiller	Thermal & Fluids Analysis Workshop, August 21-25, 2000, Cleveland, OH
22	Incorporation of Condensation Heat transfer Model into a Flow Network Code	Miranda Anthony. Alok Majumdar	Thermal & Fluids Analysis Workshop, September 10-14, 2001, Huntsville, Alabama.

	Title	Author(s)	Conference/Journal
23	Discharge Characteristics of the International Space Station (Ise) Portable Fire Extinguisher (Pfe) and the effect on Closed Volumes	Charles E Martin Paul Schallhorn Paul Wieland	SAE Paper No. 2001-01-2316
24.	Modeling of Chill Down in Cryogenic Transfer Lines	M. Cross A.K. Majumdar J. C. Bennett Jr. R. B. Malla	Journal of Spacecraft and Rockets, Vol. 39, No. 2, 2002, pp 284-289.
25	Numerical modeling of cavitating venturi – a flow control element of propulsion system	Alok Majumdar	Thermal & Fluids Analysis Workshop, August 12-16, 2002, Houston, TX
26	Numerical Modeling of Fluid Transient by a Finite Volume Procedure for Rocket Propulsion Systems	Alok Majumdar Robin Flachbart	Proceedings of ASME FEDSM'03, 4th ASME/JSME Joint Fluids Engineering Conference, Paper No. FEDSM2003-45275, Honolulu, Hawaii, USA, July 6-10, 2003
27	Numerical Modeling of Thermofluid Transients During Chilldown of Cryogenic Transfer Lines	Alok Majumdar Todd Steadman	33rd International Conference on Environmental Systems (ICES), Paper No. 2003-01-2662, Vancouver, Canada, July 6-10, 2003.
28	Numerical Modeling of Unsteady Thermofluid Dynamics in Cryogenic Systems	Alok Majumdar	Thermal & Fluids Analysis Workshop, August 18-22, 2003, Hampton, Virginia
29	A Novel Approach for Modeling Chemical Reaction in Generalized Fluid System Simulation Program	Mehmet Sozen Alok Majumdar	39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 20-23, 2003, Huntsville, AL, AIAA 2003-4467
30	Numerical Modeling of Conjugate Heat Transfer in Fluid Network	Alok Majumdar	Thermal & Fluids Analysis Workshop, August 30- September 3, 2004, Jet Propulsion Laboratory, Pasadena, California
31	Numerical Modeling of Flow Distribution in Microfluidics Systems	Alok Majumdar Helen Cole C. P. Chen	Proceedings of Forum on Microfluidics Devices and Systems, ASME Fluids Engineering Conference, Paper No. FEDSM 2005-77378, June 19-23, 2005, Houston, Texas
32	Development and Implementation of Non-Newtonian Rheology into the Generalized Fluid System Simulation Program (GFSSP)	Roberto Di Salvo Stelu Deaconn Alok Majumdar	42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, July 9-12, 2006, Sacramento, CA, AIAA 2006-
33	Microfluidic System Simulation including the Electro-Viscous Effect	Eileen Rojas C. P. Chen Alok Majumdar	Integration and Commercialization of Macro and Nano Systems, ASME International Conference, Paper No. MNC2007-21295, Sanya, Hainan China, Jan 10-13, 2007